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Relationship of Attenuations at Ka and Ku Bands with Sea Surface Temperature of Pacific Ocean

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Abstract— Radiowave propagation can be attenuated by different atmospheric parameters like raindrops, suspended particles, aerosols and variation of temperatures in the atmosphere. Absorption and scattering through the propagating medium is highly influenced by the condition of the atmosphere. Sea Surface Temperature plays a vital role in the absorption of moisture in the several layers of the upper atmosphere from the surface level. Oceans are the major sources from where the atmosphere gets the moisture content. Thus aerosol particles content increases in the atmosphere and formation of rain drops occurs. The equivalent path length of the radiowave signal at higher frequencies gets affected by the raindrop sizes and suspended particles existing in the atmosphere. The wireless communication at present depends mostly on the higher frequency range of the electromagnetic spectrum. Ka and Ku bands belong to this higher frequency range. Our aim in the present paper is to study whether the attenuation of the radiowave at Ka and Ku bands has any relation with the monthly mean sea surface temperature of the Nino regions of Pacific Ocean.

Index Terms— correlation coefficient, Ka band, Ku band, Nino1+2, Nino3, Nino4, rain attenuation, sea surface temperature.

1 Introduction

Atmospheric disturbances can strongly affect radio wave propagation. Raindrops can both absorb and scatter signals propagating in the atmosphere. The radio wave propagation is largely affected by the atmospheric parameters such as pressure, temperature, humidity and suspended particles, [1]. The effects are significant by rain attenuation in satellite communication and broadcasting using frequency of higher than 10 GHz, [2], [3]. The effect of propagating medium (atmosphere) increases with the increase of the frequency of the signal, [4]. Maekawa et al. [5] cited in 2006 that rain attenuation of radio wave is significant in satellite communications using frequencies of higher than 10 GHz such as Ku band (12-18 GHz) and Ka band (27-40 GHz) [6], [7]. Absorption and scattering by rain at frequencies above 10 GHz can cause a reduction in transmitted signal amplitude (attenuation), which in turn reduce the reliability, availability and performance of the communications link, [8]. Rain rate and rain attenuation predictions are one of the vital steps to be considered when analyzing a microwave satellite communication links at the Ku and Ka bands, [9]. Atmospheric effects play a major role in the design of satellite-to-earth links operating at frequencies above 10 GHz, [9]. Rain attenuation of satellite communication links that occurs along the propagation path in the air is basically predicted from rainfall rate observed on the ground, [5]. Most effective satellite communications are observed in very high frequency bands like Ka or millimeter wave bands. Ku-band radio waves tend to be attenuated by rain more significantly than C-band (4-8 GHz) radio waves, [5]. Tropospheric propagation of signals is largely influenced by local effects, while Ku, Ka band propagations are largely termed as Ionospheric propagation. The rain attenuation increases with frequency and also regional locations, [10]. Due to the fast growth in telecommunication, the demand over bandwidth usage is ever growing in fields like multimedia (such as video conferencing), internet applications and others, which require very high data rate transmissions. As the electromagnetic spectrum becomes extremely congested, the need for higher frequencies such as C (4 to 8 GHz), Ku (12 to 18 GHz), Ka (26.5 to 40 GHz), and V (40 to 75 GHz) bands are in rise, [11].

El Nino Southern Oscillation (ENSO) is a global atmospheric

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feature and an important manifestation of the tropical ocean-atmosphere-land coupled system, [12]. El Nino and La Nina occur due to the southern oscillation in the tropical Pacific Ocean over the Nino regions during the certain cycle period. These Nino regions are widely spread within Nino1+2 (0-10S / 80W-90W), Nino3 to Nino3.4 (5N-5S / 90W-150W) and Nino4 (5N-5S / 150W-140E), (fig.1) [13]. Sea Surface Temperature (SST) of Pacific Ocean is more than normal in El Nino period and less than normal in La Nina period. El Nino-La Nina has some effects on different atmospheric events occurring in several places through out the globe. It has been found that ENSO event influences monsoon rainfall in some parts of Asia, [14]. Our aim is to find the relationship, if exists, between the Sea Surface Temperatures (SSTs) of Nino regions and the attenuations measured at Ku and Ka bands in Osaka, Japan. The city of Osaka is situated at 34.41°N/135.30°E, (Fig. 1) at the mouth of the Yodo River on Osaka Bay in Japan.

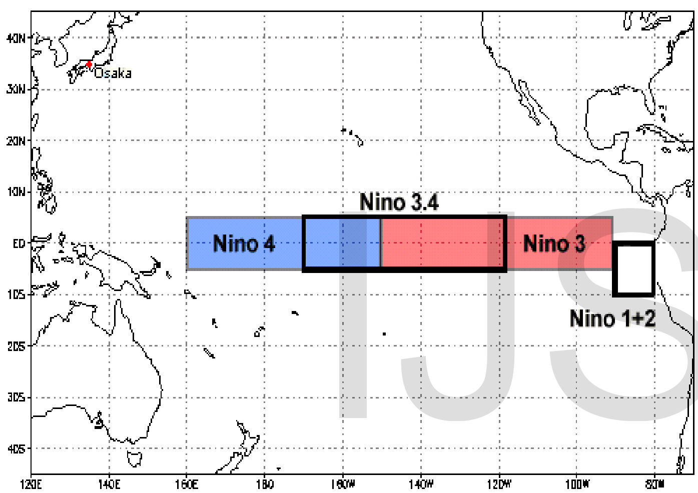

Fig.1. Geographical locations of Nino regions of Pacific Ocean and Osaka, Japan.

2 Data

Yearly data of rain attenuation is observed for the period of twenty one years from 1986 to 2006. During this period, the Ka-band satellite signal attenuation has been observed using the beacon signal of Japan's domestic communications satellites. The Ku-band attenuation has been observed using the signal of Japan's Broadcasting Satellite (BS).

Sea surface temperatures (SSTs) of Pacific Ocean are collected for different Nino regions. The monthly mean SST data over Nino1+2, Nino3, and Nino4 regions of the tropical Pacific Ocean were obtained from the website http://www.cpc.ncep.noaa.gov/data/indices/sstoi.indices during the period of 21 years (1986-2006).

3 Methodology

The year-wise attenuations at Ka-band signal propagation during 21 years (1986-2006) are correlated with the monthly mean Sea Surface Temperatures (SSTs) for the corresponding years collected from each Nino region of Pacific Ocean, i.e., Nino1+2, Nino3 and Nino4. Likewise the attenuations at Ku-band during the same time period are also correlated with the SSTs of each of the Nino1+2, Nino3 and Nino4 regions for corresponding years.

Correlation Coefficient indicates the relationship between two variables. If one type of variable increases (or decreases), and correspondingly the other also increases (or decreases), then the correlation between them will be positive. Conversely, if one variable increases (or decreases), and correspondingly the other variable decreases (or increases), the correlation between them will be negative.

Let $(x_i, y_i); i = 1,\ldots, n$ be the given two dimensional data. Let

$$\bar{x} = (\sum_{i=1}^{n} x_i)/n \text{ and } \bar{y} = (\sum_{i=1}^{n} y_i)/n \cdot \quad (1)$$

Then, we sample the variance of X, denoted by var(X), is defined as

$$\operatorname{var}(X) = (\sum (x_i - \bar{x})^2)/n \quad (2)$$

sample variance of Y, denoted by var(Y), is defined as

$$\operatorname{var}(Y) = (\sum_{i=1}^{n} (y_i - \bar{y})^2)/n \quad (3)$$

and the sample covariance, denoted by covar(X, Y), is defined as

$$\operatorname{cov}ar(X,Y) = (\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y}))/n \quad (4).$$

Then the sample correlation coefficient, denoted by *r*, is defined as

$$r = \frac{\operatorname{cov}ar(X,Y)}{\sqrt{\operatorname{var}(X)\operatorname{var}(Y)}}. \quad (5)$$

The sample correlation coefficients are evaluated by two-tailed t test. In this work, the level of significance $\alpha = 0.05$ is considered. Here, *r* is the correlation coefficient calculated on the basis of *n* given two dimensional vectors. The tabulated values of correlation coefficients for degrees of freedom (n-2) and for the level of significance $\alpha = 0.05$ are found from the statistical table, [15]. If the statistically tabulated value of the correlation coefficient does not exceed the calculated correlation coefficient, then it is accepted, otherwise it is rejected. The correlation coefficient then is referred as 'significant positive' (if $r > 0$) or 'significant negative' (if $r < 0$). Insignificant correlation coefficient is indicated when the magnitude of the calculated correlation coefficient is less

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than the statistically tabulated value of the correlation coefficient.

4 RESULTS

The correlation coefficients between the month-wise data of the sea surface temperature of each of the Nino1+2, Nino3, Nino4 regions and year-wise rain attenuation (in dB) for each of Ka and Ku band over a period of 21 years from 1986-2006 have been obtained by applying Pearson correlation statistical function. Fig. 2 and Fig. 3 show the graphs of these correlation coefficients versus the monthwise SSTs for the span of 21 years.

Here, monthwise SST data of each Nino region of Pacific Ocean is correlated firstly with Ka-band rain attenuation data of each corresponding year. The three correlation graphs for each of Nino1+2, Nino3 and Nino4 regions are drawn in Fig. 2. These three graphs are shown by three different colours indicating the correlation values for the SSTs of three different Nino regions.

Similarly the same process is followed to draw Fig. 3 which represents the correlation coefficients between monthly mean SST data for each of the Nino regions and yearwise Ku-band attenuation data.

The plots for Nino1+2, Nino 3 and Nino 4 are then taken together and compared over a span of twenty one years (1986 to 2006).

It has been found from Fig. 2 and Fig. 3 that the magnitude of most of the correlation coefficients between attenuation and the SSTs of the three Nino regions of the Pacific Ocean are negative. It significies that for the months when the SST increases the attenuation in Ka and Ku bands decreases and vice versa. It is very interesting to note that Ku band attenuation shows a significant negative relationship with the SSTs (Fig. 3).

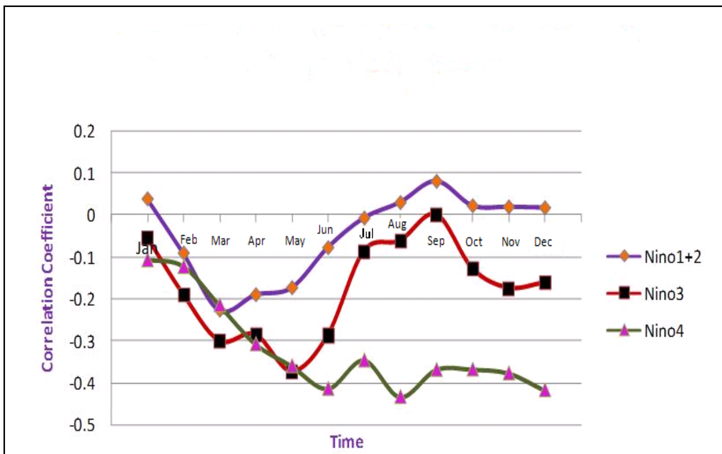

Fig.2. Correlation graph of Ka-band attenuations with Nino SSTs

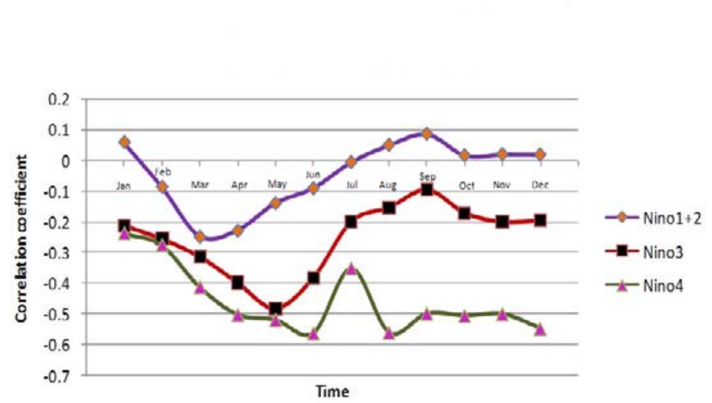

Fig.3. Correlation graph of Ku-band attenuations with Nino SSTs

From Fig. 2, it is clearly seen that the correlation coefficients vary in different months. The standardized Pearson correlation coefficient value as per RMM statistical table [15] for 21 years (degrees of freedom is 19) is 0.433. In case of the Ka band attenuations, it is observed that the correlation coefficients of the SST of Nino1+2 region with Ka-band attenuation show no significant value in any of the months. The correlation coefficients of the Nino3 region SST show similar behavior. It is also the same for the Nino4 region except for the month of August where the correlation coefficient has a negative significant value (–0.434). Over all, it is found that there is no significant co-relationship between the Ka-band attenuations and Nino SSTs of Pacific Ocean.

In case of Ku band attenuations (Fig. 3), it is seen that the Nino1+2 SSTs have no significant correlation coefficient value. The correlation coefficients of the SSTs of Nino3 region have almost the same nature except that there exists a significant negative value (-0.483) in the month of May. However, it is a completely different scenario for Nino4 region. Here the correlation coefficients relating the SSTs with Ku band attenuations bear significant negative values for all the months except January, February, March and July. The graph shows that the values of correlation coefficients are decreasing from the month of March to the month of June. The curve passes through the significant negative correlation coefficient values of (-0.50431) and (-0.52138) during the months of April and May respectively and reaches the highest significant negative correlation coefficient value of (-0.56515) in the month of June. The graph rises abruptly to an insignificant negative value in the month of July and then falls off to a significant negative correlation value of (-0.56335) in the month of August. Thereafter it passes through the significant negative correlation values of (-0.50064), (-0.50779) and (-0.50224) in the months of September, October and November respectively and ends in the month of December with a significant negative correlation coefficient of

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(0.54954). Since the yearly rain attenuations are related to these respective correlation coefficients, it can be inferred that a connection may exist between the yearly Ku-band rain attenuations and SSTs of Nino4.

It is clearly evident from the graph of Figure 3 that Nino4 region is our point of interest because it is the region with the highest number of significant negative correlation coefficient values. This clearly suggests a possible relationship between the Nino4 SSTs and the yearly Ku-band rain attenuation particularly in the region of Osaka, Japan.

5 Conclusion

The sea surface temperature of the Nino regions of Pacific Ocean has insignificant correlation with the ka-band attenuations. It indicates that there is no relation between SST of Pacific Ocean and Ka-band attenuations in Osaka, Japan. But it is found that there exists significant negative correlation coefficients between SST of Nino4 region and Ku-band attenuations in Osaka, Japan. SSTs of Nino1+2 and Nino3 regions do not bear any significant correlation with Ku-band attenuations in Osaka. It is to be pointed out that Nino1+2 and Nino3 regions are situated geographically far away from Osaka, whereas Nino4 region is nearer to Osaka. Probably, SST of Nino4 region has some influence on the rain attenuation of Ku band in Osaka because Nino4 and Osaka are nearer to each other. It has been revealed from this study that geographical locations may affect certain atmospheric features which may have an influence on radiowave propagation at the higher frequencies of Ku band. A thorough scientific research is required to investigate the proper reason behind this interesting relationship between Ku-band propagation in Osaka of Japan and SST of Nino4 region of western Pacific Ocean.

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