

# Depolarization Effects of Microwave Signals Due to Dust Storms Particles

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**Abstract-** The microwave signal depolarization caused by storms particles is one of the major problems in utilizing microwave bands for terrestrial and space communication especially at desert and semi desert area. This aim of this research is to study the effects of dust particles on the polarization state of microwave signal. The calculations, which were based on the probability density of Iraqi dust storms, were performed for six frequency bands of microwave signals. Results showed that strong and severe dust storms can highly depolarized the microwave signal through induced differential attenuation and differential phase shift. These two parameters also depends on the shape of the dust particle, particles with low axial ratio can induce relatively high differential attenuation and differential phase shift, and therefore cause more depolarization in the signal. It was found that the relative humidity can only affect the differential attenuation and this effect is minimized at band of high frequency.

**Index Terms-** Dust storm, Microwave signal, Depolarization

## I. INTRODUCTION

Dust and sand storms occur in many parts of the world, especially in the Middle East and arid parts of Asia, The theory of microwave propagation in sand storms has received much attention in the literature owing to the importance of radio relay, communication and remote sensing. The attenuation of the microwave signals in dusty media may arise from two physical mechanisms, absorption and scattering of energy by the suspended dust particles. Different models are available in the literature to predict the total cross-section efficiency (extinction), for the suspended (dust) particles. All these models require knowledge of the electrical properties of the scattering particles, i.e. dust dielectric constant, dust particles geometry, dust particles size distribution and visibility during the dust storms. A number of papers have addressed the problem of prediction of the amount of attenuation and phase shift in sand storms [1]-[5]. Haddad et al. [6] examined the attenuation of the uniform sandstorms and the effects of moisture contents. McEwan et al. [7] analyzed the depolarization effects of non-uniform particles and present an assessment of attenuation and back scattered properties associated with the dust storm. Salman et al. [8] described the theoretical bases of non-spherical particles alignments and its effects. Elabdin et al., [9] presented a mathematical model developed to characterize the microwave signal attenuation due to dust. This model enables a convenient calculation of the microwave signal path attenuation which relates attenuation to visibility, frequency, particle size and complex permittivity. Mohammed [10] studied the effect of severe dust storms with visibility less than 1 km on some aspect of microwave propagation especially attenuation and depolarization at 12 GHz. Sharif [11] describe the dusty media properties related to microwave signal propagation, and to give numerical values and statistics of these parameters for dust storms that frequently occur in Sudan. Musa and Bashir [12] investigated the electromagnetic waves propagation in dust Storms at millimeter wave band. They found that the attenuation by the proposed formula and the published formulae show close agreement. Attenuation in dry dust is only significant when the visibility becomes severe or at lower millimetric wave bands. The aim of this research is to model and compute depolarization of microwave signals induced by dust storms in Iraq.

## II. ELECTROMAGNETIC WAVE ATTENUATION AND PHASE SHIFT IN DUST STORMS

The horizontal and vertical complex propagation constants of the medium  $K_{H,V}(m^{-1})$

$$K_{H,V} = K_o + \frac{\pi K_o}{12} \int_{D_{min}}^{D_{max}} Q_{H,V}(e, m) D^3 N(D) dD \quad (1)$$

where  $D$  is the diameter of sphere with volume equal to that of spheroid,  $N(D)$  is the particle size distribution ( $m^{-4}$ ),  $D_{max}$  and  $D_{min}$  are the maximum and minimum diameter of particle.  $K_o$  is the free space propagation constant ( $m^{-1}$ ) [ $K_o = \frac{2\pi}{\lambda}$  where  $\lambda$  is the wavelength (m)].  $Q_{H,V}$  are functions of the eccentricity,  $e$ , and the complex refractive index,  $m$  of the particle as follows [13]:

$$Q_{H,V} = \frac{m^2 - 1}{1 + P_{H,V} (m^2 - 1)} \quad (2)$$

where

$$P_V = \frac{1}{e^2} \left[ 1 - \left( \frac{1 - e^2}{e^2} \right)^{\frac{1}{2}} \text{sine} \right] \quad (3)$$

$$P_H = \frac{(1 - P_V)}{2} \quad (4)$$

The eccentricity is a function of the semi-minor and semi-major axes ( $a$  and  $b$ ) of the particle

$$e^2 = 1 - \frac{a^2}{b^2} \quad (5)$$

The complex refractive index is related to the dielectric constant of the particles,  $\epsilon$ , by

$$\epsilon = \epsilon' - i\epsilon'' = m^2 \quad (6)$$

For sand and dust storms it is more convenient to express  $K_{H,V}$  in terms of the probability density function  $P(D)$  [14]:

$$K_{H,V} = K_0 + \left( \frac{5.76 * 10^{-4} K_0}{V_0} \int_{D_{\min}}^{D_{\max}} Q_{H,V}(e, m) D^3 P(D) dD \right) \left( \int_{D_{\min}}^{D_{\max}} D^2 P(D) dD \right)^{-1} \quad (7)$$

The one way differential attenuation,  $\Delta A$ , and one way differential phase shift,  $\Delta\phi$ , for horizontally polarized waves are defined by [13]:

$$\Delta A = 0.4343 \times 10^4 \text{Im}(K_H - K_V) \quad (8)$$

$$\Delta\phi = \frac{180}{\pi} \times 10^3 \text{Re}(K_H - K_V) \quad (9)$$

where  $\text{Re}$  and  $\text{Im}$  signifies the real and imaginary parts of  $(K_H - K_V)$ .

In this work, the probability function for Iraqi dust storms reported by [8] was used:

$$P(D) = \frac{1}{\sqrt{2\pi D \ln \delta}} \exp\left(-\frac{1}{2 \ln \delta} \ln^2\left(\frac{D}{\bar{D}}\right)\right) \quad (10)$$

where  $\bar{D}$  is median geometrical diameter and is equal to  $9.488 \times 10^{-6}$  m and  $\delta$  is the geometrical standard deviation and is equal to 4.512.

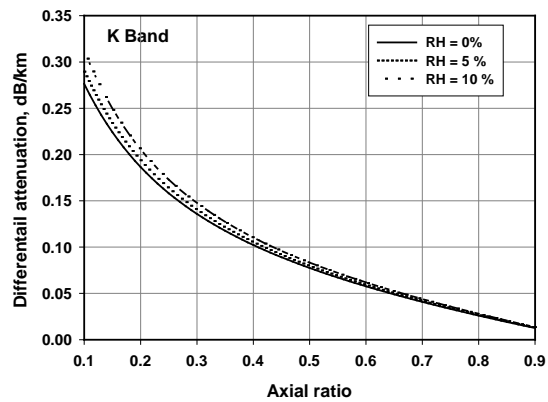
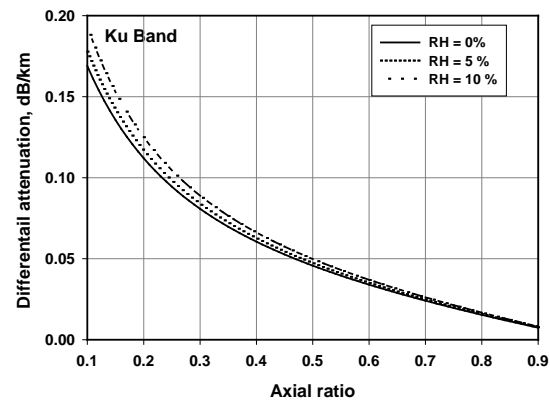
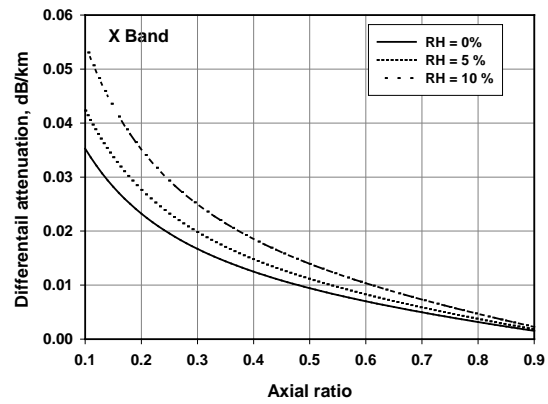
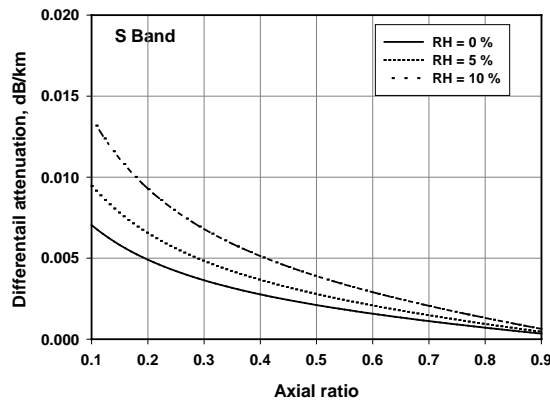
### III. RESULTS AND DISCUSSION

The depolarization model described in the previous section was used to compute the differential attenuation and phase shift for the six microwave bands (S, X, Ku, K, Ka and W). Range of frequency and dielectric constants for each of these bands are listed in Table I. The computations were carried out for different axial ratios and visibilities. Three relative humidity values were considered (0, 5 and 10%). Figure 1 shows the results for the differential attenuation versus axial ratio. It is seen that for the frequency bands the differential attenuation decreases exponentially with increasing the axial ratio. This is due to the fact that higher axial ratios result from closer major and minor axes which cause smaller differential attenuation. It is also observed that the effect of relative humidity is function of both frequency and axial ratio. Relative humidity has major impact at lower frequency (S band) and this effect is small at higher frequency. It is also seen that relative humidity is effective at low values of axial ratio and it this effect is almost negligible at higher axial ratios. Figure 2 gives the results of differential phase shift calculations. It is obvious that the behavior of differential phase shift with axial ratio is similar to that of the differential attenuation. The differential phase shift is less sensitive to the change in relative humidity. To investigate the effect of frequency on differential attenuation and differential phase shift, the results of computations presented in Figures 1 and 2 are grouped in Figure 3 for relative humidity of 0%. It is evident dust particles induced high values of differential attenuation and differential phase shift for waves of high frequencies such as W band. Waves of low

frequency band like S band is less depolarized by dust particles. Figures 4 and 5 give the results of computations for attenuation and differential phase shift versus visibility for dust particles of axial ratio of 0.7. Visibility is a parameter used to indicate the severity of dust storms. These results illustrate that differential attenuation and differential phase shift have sensible values when visibility is too low. This suggest that severe dust storm can cause a high depolarization in propagating signals. The results also show that change in relative humidity has small effect of on differential attenuation at S and X bands and almost frequency bands. The computations of Figures 4 and 5 for relative humidity of 0% for all frequency bands are grouped in Figure 6. It is seen that high frequency bands are notably affected even when visibility is high.

Table I. Listing of dielectric constants at various frequencies measured by the indicated investigators.

Band	Frequency (GHz)	$\epsilon'$	$\epsilon''$	Reference
S	3-4	4.56	0.25	[3]
X	8-12	5.73	0.42	[15]
Ku	12-18	5.50	1.30	[16]
K	18-26.5	5.10	1.40	[16]
Ka	26.5	4.00	1.33	[16]
W	80	3.50	1.64	[16]



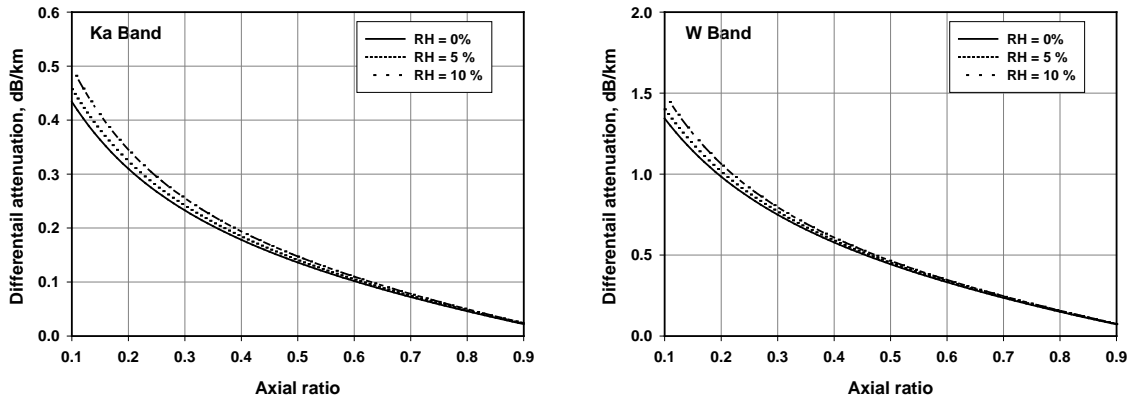
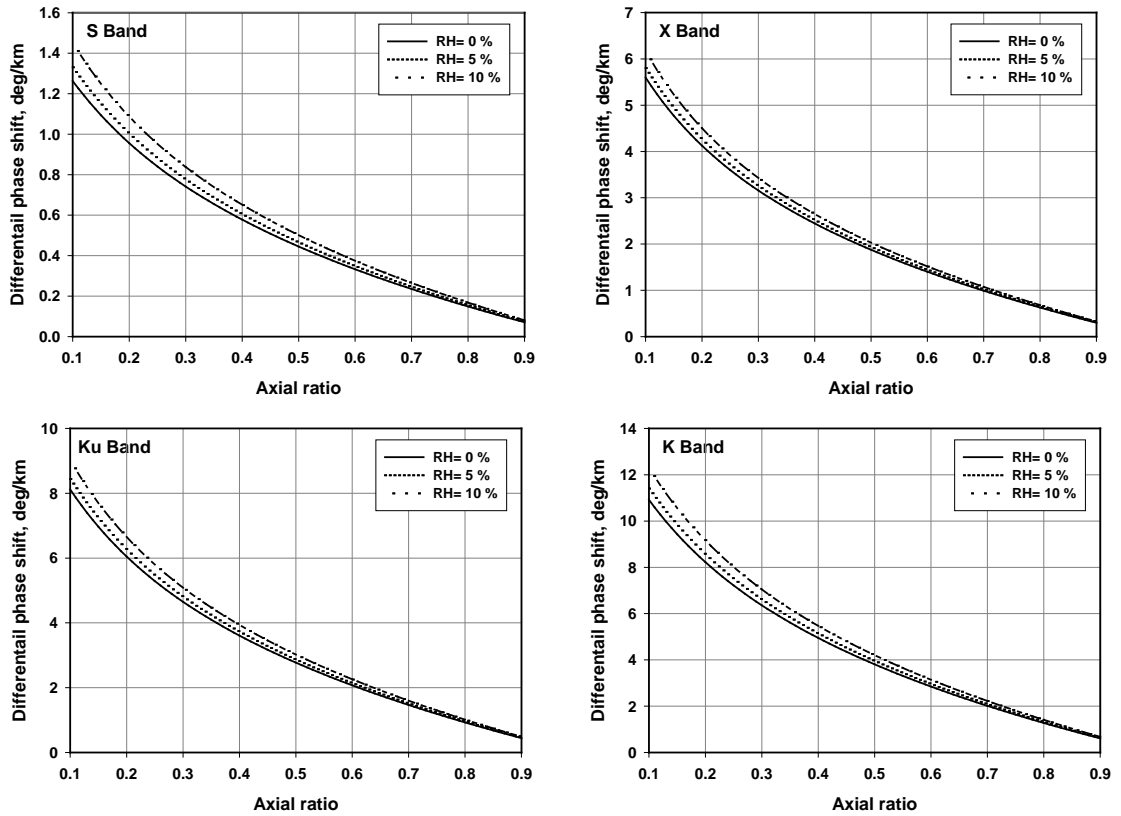


Figure 1: Differential attenuation versus axial ratio for different relative humidity and visibility of 10 m.



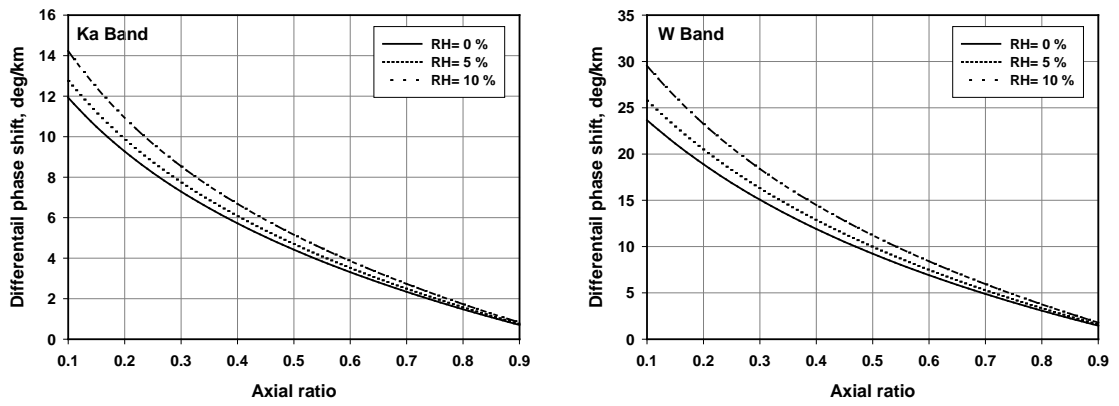


Figure 2: Differential phase shift versus axial ratio for different relative humidity and visibility of 10 m.

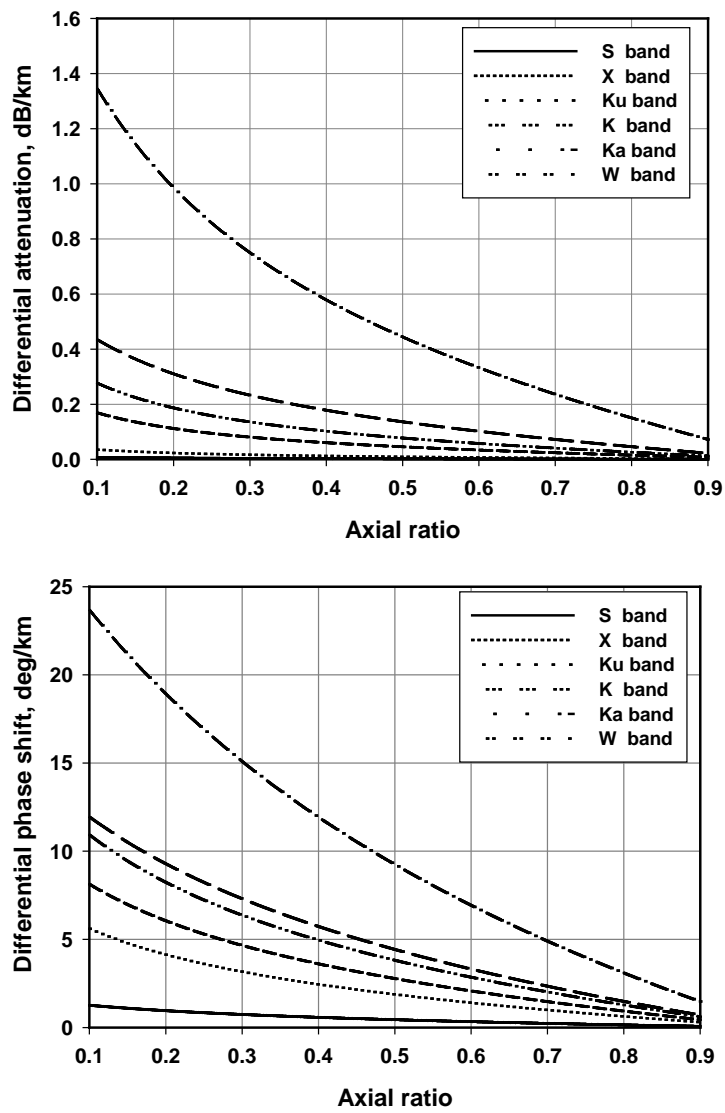


Figure 3: Differential attenuation (top) and differential phase shift (bottom) versus axial ratio for the six microwave bands at relative humidity of 0% and visibility of 10 m.

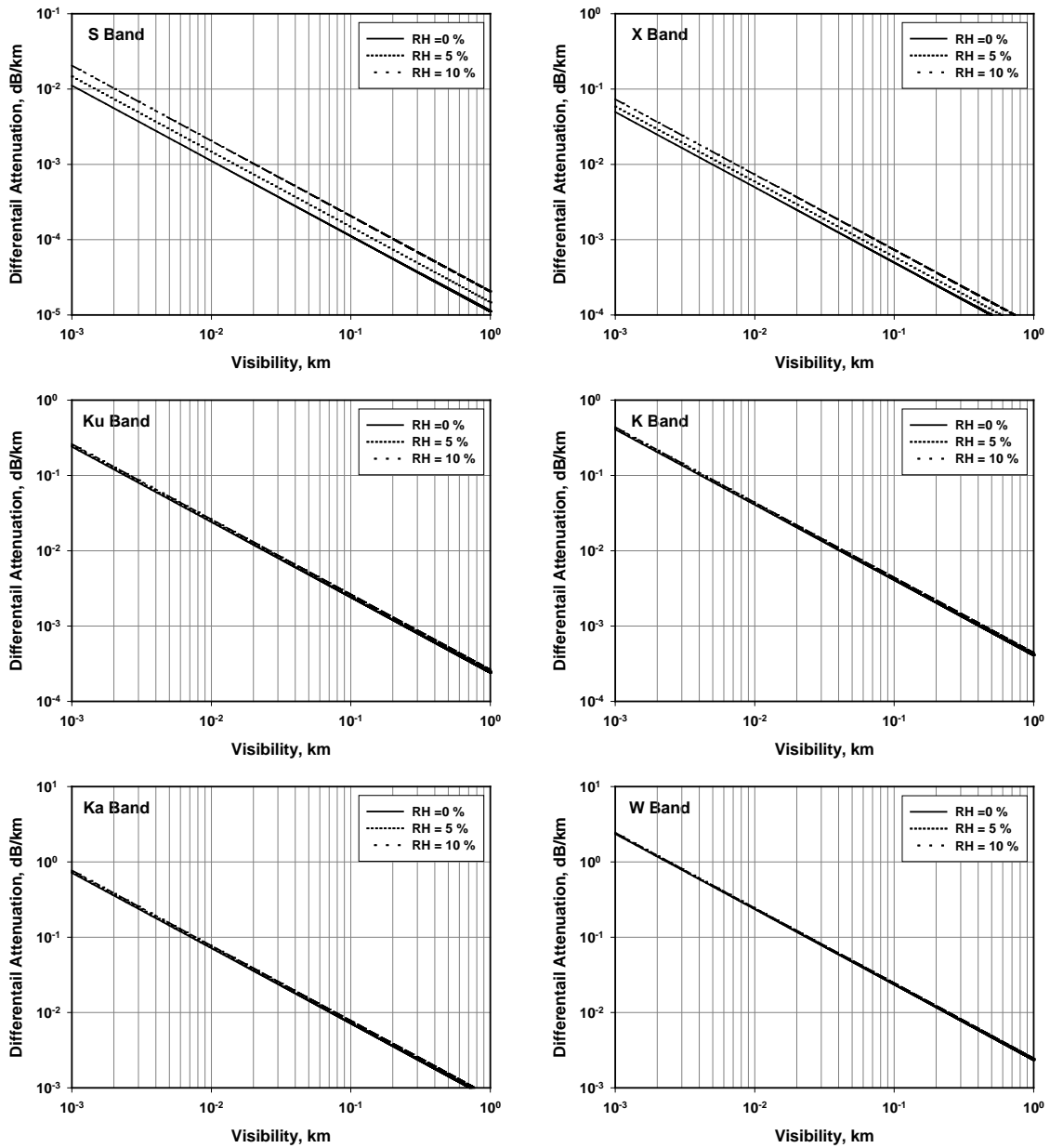


Figure (4): Differential attenuation versus visibility for different relative humidity.

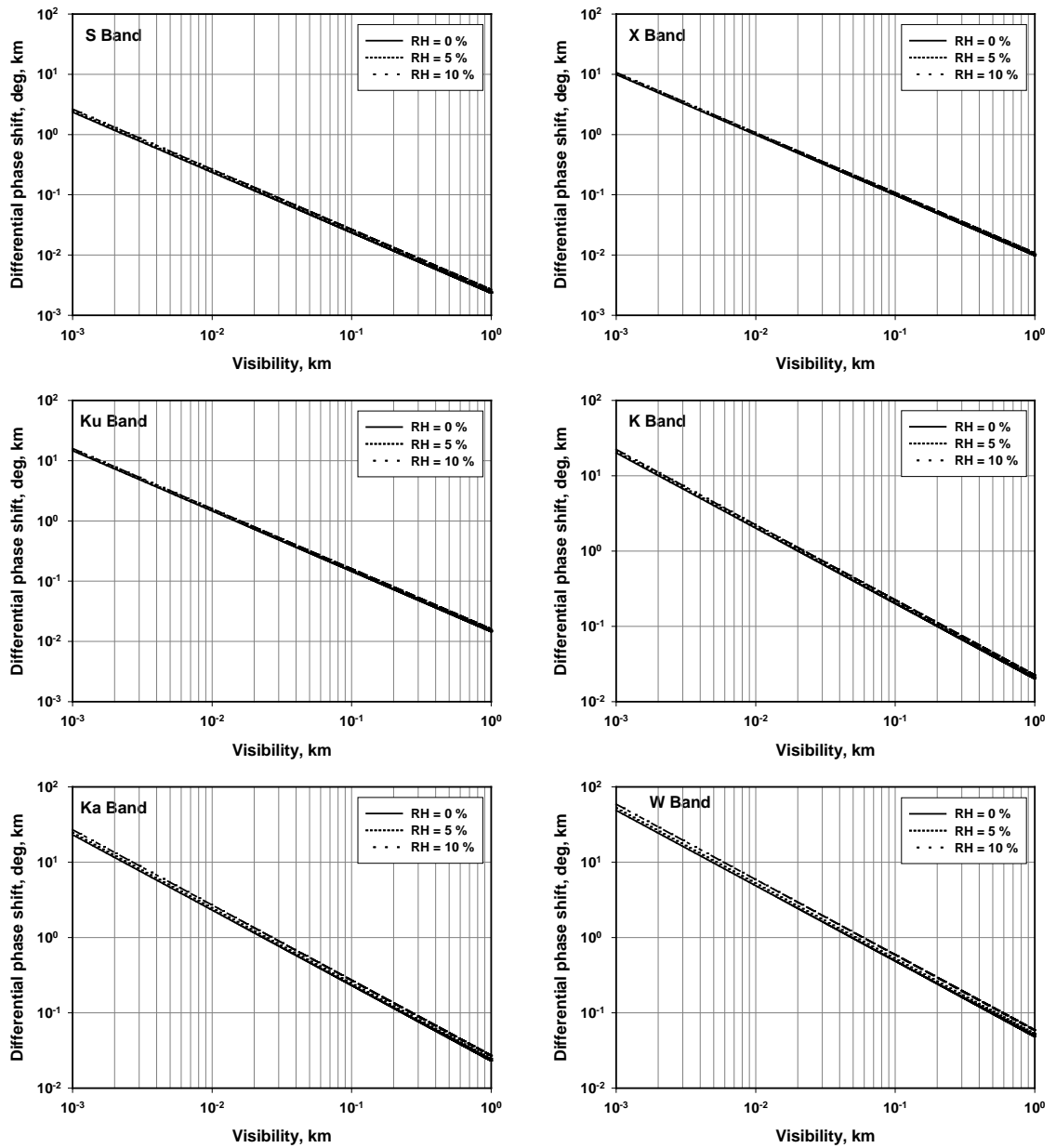


Figure (5): Differential phase shift versus visibility for different relative humidity at axial ratio of 0.7.

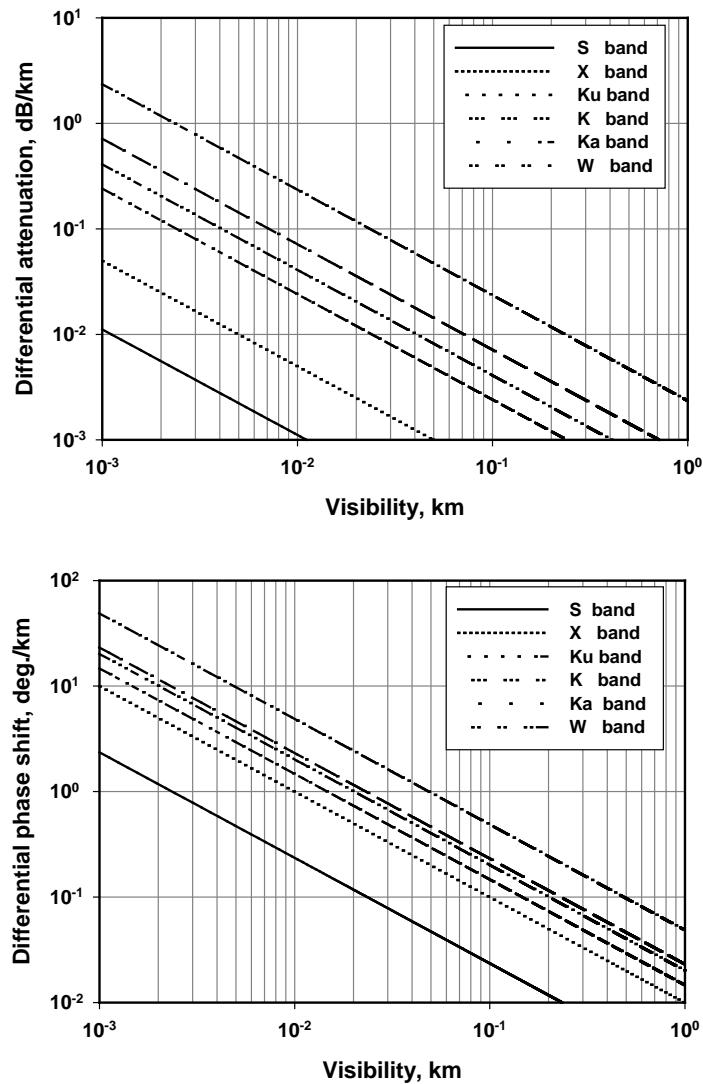


Figure (6): Differential attenuation (top) and differential phase shift (bottom) versus visibility for the six microwave bands at relative humidity of 0%.

#### IV. CONCLUSION

This research investigates the depolarization of microwave signals caused by non-spherical dust storms particles. Six microwave different bands were considered and calculations were made on the basis of the probability density function of Iraqi dust storms. Results suggested that induced differential attenuation and differential phase shift are high when axial ration of particles are too small and visibility is low. It was found that differential attenuation is more sensitivities to relative humidity than differential phase shift particularly for low frequency bands. Higher frequency bands are more depolarized by dust particles than low frequency bands.

#### REFERENCES

- [1] T. S. Chu, "Effects of Sandstorms on Microwave propagation," The Bell System Technical Journal, 1979, 58, pp. 549-555.
- [2] J. Neves, and P. A. Watson, "Cross-polarization, differential attenuation and differential phase shift measured on a 36.5 GHz terrestrial link," URSI Commission F Symp., Canada, preprints,1980, pp 5.1.1-5.1.6.
- [3] S. I. Ghobrial, "The effect of sand storms on microwave propagation," in Proc. Nat. Telecommunication Conf., vol. 2, Houston, Texas, 1980, pp. 43.5.1-43.5.4.
- [4] J. Goldhirsh, "A parameter review and assess of dusty medium of attenuation and backscatter properties associated with dust storms over desert regions in the frequency range of 1 to 10 GHz," IEEE Trans. Antenna Propagat., 1982, Vol. AP-30 No. 6, pp 1121 - 1127.
- [5] A. J. Ansari, and B. G. Evans, "Microwave propagation in sand and dust storms," Inst. Elect. Eng. Proc., VI, 1982, 129, pt. F, No. 5, pp. 315-322.



- [6] S. Haddad , M. J. Salman, and R. Jha " Effect of sand/dust storms on some aspects of microwave propagation," URSI Commission F Belgium, 1983.
- [7] N. Mc Ewan, and S. Bashir, "Microwave propagation in sand and dust storms: the theoretical basis of particle alignments," Third International Conference on antenna and propagation IEE Publication. 1983, 219, pp. 40-44.
- [8] S. Abdulla, H. Al-Rizzo, and M. Cyril, "Particle-size distribution of Iraqi sand and dust storms and their influence on microwave communication systems," Antennas and Propagation, IEEE Transactions , 1988, . 36, pp. 114-126
- [9] Z. Elabdin, M. R. Islam, O. O. Khalifa, and H. E. A. Raouf, "Mathematical model for the prediction of microwave signal attenuation due to duststorm," Progress In Electromagnetics Research M, 2009, 6, pp. 139–153.
- [10] Mohammed B. A., "Prediction of microwave attenuation due to duststorms over Iraq," AL- Mustansiriyah J. Sci., 2010, 21, pp. 98-107.
- [11] Sharif S. M., "Dust Storms Properties Related to Microwave Signal Propagation," UofKE J., 2011. 1 pp. 1-9.
- [12] A. Musa and S. O. Bashir, "Electromagnetic waves propagation in dust storms at millimetre wave band," Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS), 2013 4, pp 162-167.
- [13] S. Z. Dusan, and S. Ilana, "Depolaization of radiowaves by atmospheric hydrometeros in erath-space path ," Radio Sceince, 1981, 16, pp 781-812.
- [14] K. J. Al-Jumaily, " Depolariation effects due to sand and dust storms at 9.35 GHz ," Al- Mustansiriyah J. Sci, 1998, 21, pp. 69-74.
- [15] S. M. Sharif, "Chemical and Mineral Composition of Dust and Its effect on Dielectric Constant," IEEE Trans. On Geosciences and Remote Sensing, 1995, 33, pp 353-359.
- [16] Y. Ruike, Wu Zhensen, and Y. Jinguang, "The Study of MMW and MW attenuation considering multiple scattering effect in sand and dust Storms at slant paths," International Journal of Infrared and Millimeter Waves, 2003, 24, pp. 1383-1392.

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