P16.1 INSTANTANEOUS FREQUENCY SCALING OF MICROWAVE ATTENUATION THROUGH RADAR MEASUREMENTS

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1. INTRODUCTION

It is a common experience that atmospheric precipitation can greatly affect the propagation of radio waves at frequencies above 10 GHz in various ways and that these effects must be taken into account in the design of microwave terrestrial and satellite links. Among these effects, the most serious is rain induced attenuation. At a given frequency, attenuation depends on the length of the radio path, on the rain profile and on the rain drop size distribution DSD.

Meteorological radars are unique tools for their ability to detect with great spatial detail precipitation over a large area and these data properly calibrated are unvaluable input for propagation studies. In most applications they are calibrated on a statistical basis[1] (i.e. reflectivity Z is usually converted into rain intensity). Nevertheless, there are situations where an "instantaneous" calibration which takes into account the actual DSD, highly variable in nature (Capsoni *et. al.*, 1983) , is required.

2. THE EXPERIMENT

At the experimental station sited at Spino d’Adda, 30 km east of Milan, Italy a S band Doppler non polarimetric meteorological radar is colocated with a satellite station operating in the framework of the Italsat propagation experiment. The main characteristics of the radar are: 500KW peak power, 0.5 μs pulse duration, 2° beamwidth, 79 dB dinamic range. The radar uses a fast duplexer with a recovery time shorter than 2 μs that allows the data collection from a minimum range of 300 m which is approximately the far field zone of the antenna. During various rain events joint measurements along a 38° slant path of attenuation at the satellite frequencies of 18, 40 and 50 GHz have been recorded toghether with the radar reflecivity profiles along the same path. For each rain event, the relationship between specific attenuation α and reflectivity Z needed to estimate the fade levels from radar measurements was obtained at the lowest operating frequency through a best fit procedure that forced the predicted values to agree with the measured ones (Goldhirish, 1980). In many cases this best fit presented a quite high correlation coefficient and this fact was assumed as an indicator that the relation found could well describe the rain process of the event, on the average, both in time (event duration) and in space (satellite path). Consequently, it was assumed to contain also information about the DSDs within the event. In order to prove this last statement the α−Z relation derived at 18 GHz was used to deduce the DSD parameters and, in turn, to derive the α−Z relation at the other two satellite frequencies. In this way we obtained the radar−predicted time series of attenuation at 40 and 50 GHz to be compared with the satellite measurements.

3. THE THEORY

Let us consider the relation α−Z at a given frequency *f*:

$$\zeta(f)=a(f)Z^{b(f)} \quad . \quad (1)$$

If we assume that the DSD is of the gamma type and that the extinction cross sections of the drops can be modelled as a function of their diameter:

$$N(D)=N_0 D^{\mu} e^{\left(\frac{-(3.67+\mu)D}{D_0}\right)}, \quad (2)$$

$$\zeta(D)=c(f)D^{n(f)}, \quad (3)$$

it follows that reflectivity and specific attenuation can be rewritten as:

$$Z=\frac{N_0\Gamma(d_{1,d})D_0^{d_1}}{g^{d_1}}, \quad (4)$$

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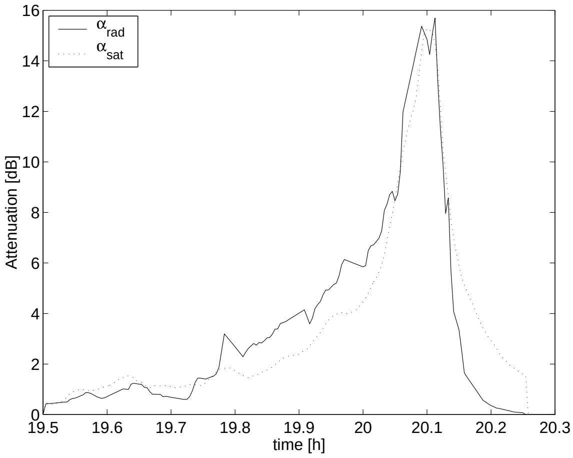

Figure 1: Fitting between satellite measured attenuation at 18.39 GHz and attenuation computed from radar reflectivity.

$$\zeta(f)=\frac{c'(f)N_0\Gamma(d_{2,d})D_0^{d_2}}{g_{2,}^{d}} \qquad (5)$$

where Γ is the modified gamma function, d_1=7+μ, d_2= $n(f)$+1+μ, d=6.5 mm (d=upper limit of the Γ integral), g=3.67+ μ, $c'(f)$= $4.34\times10^{-(1+n(f))}c(f)$. If the values of a and b in eq. (1) are known at one frequency f_1 as well as $c(f_1)$ and $n(f_1)$ in eq. (2), after some manipulation it is possible to evaluate N_0 and D_0 for different values of the μ parameter. Choosing another frequency f_2 and consequently applying another couple $c(f_2)$ and $n(f_2)$ one can derive $a(f_2)$, and $b(f_2)$ as a function of the $a(f_1)$, $b(f_1)$ and μ values:

$$a(f_2)=\left[\frac{a(f_1)\Gamma(d_{1,d})}{\Gamma(d_{2,d})c'(f_1)}\right]^K\frac{\Gamma(d_{3,d})c'(f_2)}{\Gamma(d_{1,d})}, \qquad (6)$$

$$b(f_2)=1-(1-b(f_1))K, \qquad (7)$$

where $d_2 = n(f_1) + 1 + \mu$, $d_3 = n(f_2) + 1 + \mu$ and $K=(6-n(f_2))/(6-n(f_1))$.

4. THE RESULTS

Fig. 1 shows the time profile of rain attenuation (date: August 24, 1994, convective storm) along the slant path at 18 GHz obtained by subtracting from the direct satellite measurements the fade contribution due to gases (oxigen, water vapor and clouds) that is not "seen" by the radar (dotted line).

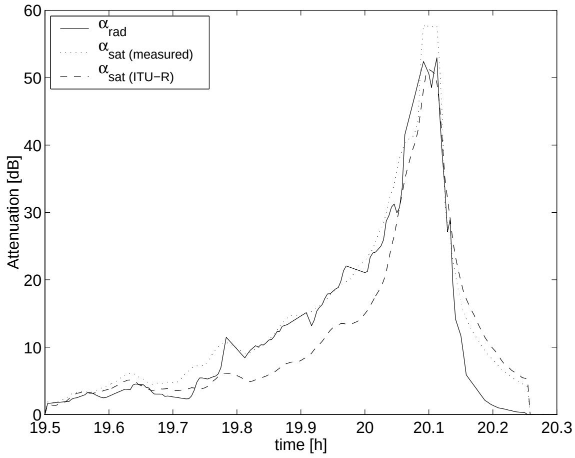

Figure 2: Attenuation as a function of time at 39.59 GHz.

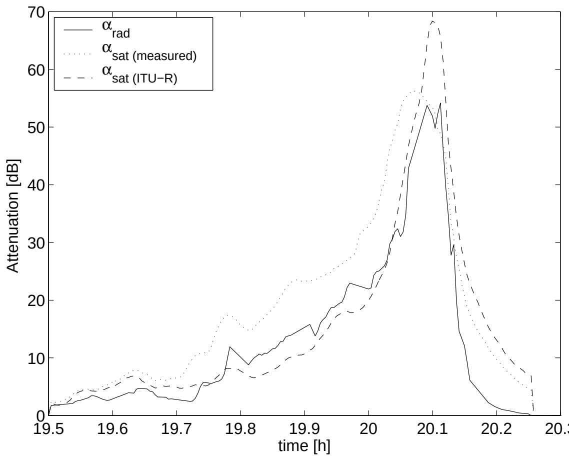

Figure 3: Attenuation as a function of time at 49.49 GHz.

The continuous line represents the estimation obtained by radar reflectivity profiles collected simultaneously along the same path with Z converted into attenuation by means of the relation $9.3\ 10^{-5}Z^{\ 0.908}$; which was obtained through a best fit procedure. The above relation was converted into the corresponding ones for the other satellite frequencies; $4.64\ 10^{-4}Z^{\ 0.874}$ at 40 GHz and $5.2\ 10^{-4}Z^{\ 0.865}$ at 50 GHz following the analytical procedure outlined in the previous paragraph where the coefficient μ has been set to zero. In fact, its variation within −2 and +3 that represents the assumed standard variability range of μ did not evidence any substantial change in the parameters a and b as well as a beneficial in the prediction. However this aspect would be analysed in deeper detail with future analyses in order to confirm it. The two relations at 40 and 50 GHz were used to evaluate the total path attenuation from radar Z profiles and the results are shown in figs. 2 and 3 respectively against the measured values. A moving average was applied to the time series of the measured attenuation collected with a sampling time of 1 s., in order to smooth out the rapid fluctuations of the signal as well as the noise superimposed; radar data have been collected at 15 s. time interval. One can appreciate how good is the prediction. Obviously as the difference in frequency increases, the prediction worsen as expected. Nevertheless it appears fairly good also at 50 GHz. On the same figures the third curve (dashed line) represents the attenuation estimated by applying the ITU−R rule (ITU−R, 1997) of frequency scaling:

$$\frac{\zeta_2}{\zeta_1} = \left(\frac{f_2}{f_1}\right)^{1.72} \frac{1+3*10^{-7} f_1^{3.44}}{1+3*10^{-7} f_2^{3.44}} \quad . \quad (8)$$

Although, strictly speaking this rule relates equiprobability attenuation values (statistical relation), it is commonly accepted it can work well also on instantaneous basis. One may appreciate that the prediction obtained by radar data is, at least, as good as the one derived by the frequency scaling rule.

Similar results were obtained in all the events that presented at the fit forcing process a correlation coefficient greater than 0.85. The analysis was not applied to the events that presented a clear brightband aloft.

5. CONCLUSIONS

This paper presents the results of a study that uses direct measurements of attenuation along a slant path at three different frequencies and joint radar reflectivity profiles along the same path in order to test a technique to "calibrate" data collected by a non polarimetric meteorological radar on event basis.After having identified the information on the DSDs of the event by means of a fit forcing procedure at the lowest satellite frequency, the attenuation at the other beacon frequencies have been obtained just using the above information. The preliminary analyses seem to confirm that the proposed technique works fairly well and is worthwhile of a deeper analysis.

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