WHITE PAPER

Rain Resilience

Delivering high Quality Ka-band Satellite connectivity in all weather conditions.

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Preface

Avanti Communications has redefined yet another aspect of the satellite communications market by making rain fade yesterday's problem. Through its investment, meticulous design and implementation of the latest technologies, it has virtually eliminated rain fade issues for its customers.

Whereas Ka-band systems have opened up a new era in satellite communications - enabling high speed, cost-effective services - the market is quickly learning that not all Ka-band satellites and operators are equal. In fact, there are enormous differences between the performance standards of competing Ka systems.

Ka-band is not a guarantee of quality, choosing the right operator is. This is why Avanti urges prospective purchasers of Ka services to closely examine both the quality and flexibility of an operator before any commercial commitment. Key considerations in choosing an operator should include:

- Coverage – do the Ka spot beams provide full coverage with no gaps?
- Beam clustering – can national service be delivered through a single hub?
- Spectral density – does the bandwidth have sufficient power per MHz to deliver the communications services required whilst ensuring the smallest possible dishes can be employed?
- Diversity – what redundancy measures are employed to guarantee high levels of availability?
- Vendor platforms – does the operator employ a single vendor strategy or provide open architecture?
- Control – to what degree do customers have the ability to control and confi gure their service?

This paper provides a detailed analysis of how Avanti guarantees high performance for customers, no matter how challenging the environment.

Executive summary

Background

In recent years, the demand for satellite communications has significantly increased. The use of Ka-band frequencies provides dramatic increases in capacity for satellite operators, while simultaneously driving down bandwidth costs, resulting in a high growth market.

Despite a compelling range of benefits, one misconceived objection sometimes raised is Ka-band's susceptibility to rain fade. This paper explores the concept of rain fade, and how through careful system design and use of the latest technology, Avanti is able to provide the highest reliability communications in even the most challenging environments. This paper demonstrates that as long as the right satellite operator is chosen, rain fade is no longer an issue.

This assertion is fully consistent with a recent contribution from the GSM Association to an ITU working group indicating how higher frequencies (Ku and Ka-band) can now be considered as alternatives to C-band services even in high rainfall territories such as equatorial Africa.

Rain fade & its impact on Ka-band

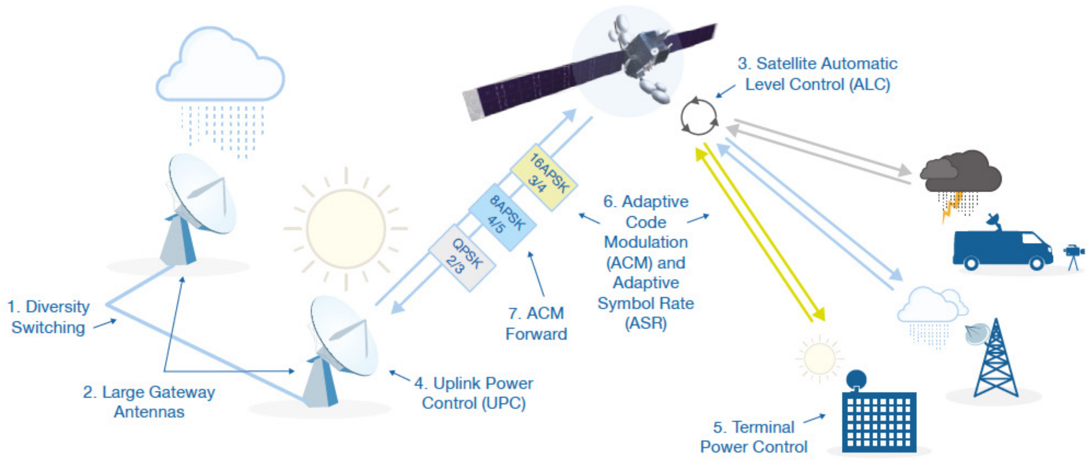
Rain fade is the absorption (or attenuation) of a microwave signal by atmospheric rain, snow or ice. The amount of signal absorbed is dependent on the size of the raindrops, snow or ice flakes, the rate of rain, snow or ice fall, and the frequency of the signal being absorbed.

Moving up the microwave spectrum towards Ka-band, the wavelength of the signal approaches the diameter of most raindrops, slow or ice flakes. It is because of this that rain, snow and ice can absorb high-frequency transmissions such as Ka-band and above.

A multi-faceted design approach to create 'rain resilience'

Many other satellite operators invest in just one type of mitigation, which is inadequate to address the various rain fade scenarios. Only a multi-faceted mitigation strategy, which combines the careful design of satellite technology and network planning, will overcome the challenges posed by poor weather.

To provide robust communications links using Ka-band several different techniques and careful system design is required. This results in the ultimate network quality.



1. Diversity Switching
2. Large Gateway Antennae
3. Satellite Automatic Level Control (ALC)
4. Uplink Power Control (UPC)
5. Terminal Power Control
6. Adaptive Code Modulation (ACM) and Adaptive Symbol Rate (ASR)
7. ACM Forward

Conclusion

When selecting a satellite operator, it is no longer sufficient to assume rain fade impacts services to the same degree. Both the type of mitigation steps, and the number of which the operator deploys, must be considered. Only when all mitigation techniques are deployed in combination, is the full cumulative mitigation benefit achieved.

Of the mitigation techniques, particular care must be given to the gateway design including large antennas and most crucially, site diversity with real-time switching capability. Only this approach provides a truly robust safety net for operators looking to ensure satellite connectivity at all times.

Causes of rain fade

Atmospheric attenuation

Atmospheric attenuation that affects signal propagation is caused by several different mechanisms:

- Rain attenuation
- Depolarisation due to rain and ice
- Antenna wetting (particularly feed)
- Gaseous absorption
- Cloud attenuation
- Melting layer attenuation
- Troposphere scintillation

By far the dominant cause is rain attenuation. However, most sophisticated link budget tools take all of the effects into account. Rain attenuation itself depends on one key parameter, the actual rain rate (in mm/hr) during the event as well as the frequency and polarisation of the signal.

Frequency dependency

At higher frequency, the impact of atmospheric attenuation is increased, though this is not a linear monotonic function. For example, the attenuation caused by gaseous absorption at around 24/25 GHz is higher than at either 20 GHz or 30 GHz (Ka-band FSS down/uplink) due to the presence of water vapour (H2O) and another much higher peak at 60 GHz due to Oxygen (O2).
See Figure 1.

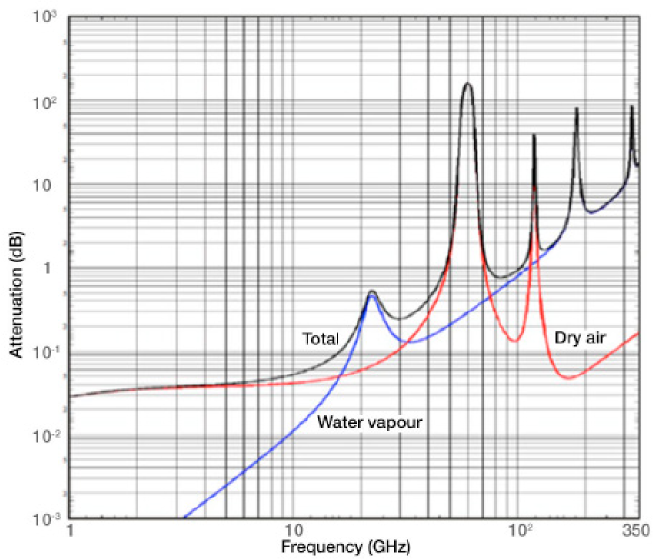


Figure 1: Specific rain attenuation (dB/Km) due to gaseous absorption with frequency (GHz)

The dependency of rain fade (at a given rain rate) with frequency is shown in Figure 1. In the usual Satcoms bands, Ku and Ka (10 to 30 GHz) the increase is a reasonably linear logarithmic function, with an approx. 2 dB increase for a doubling in frequency.

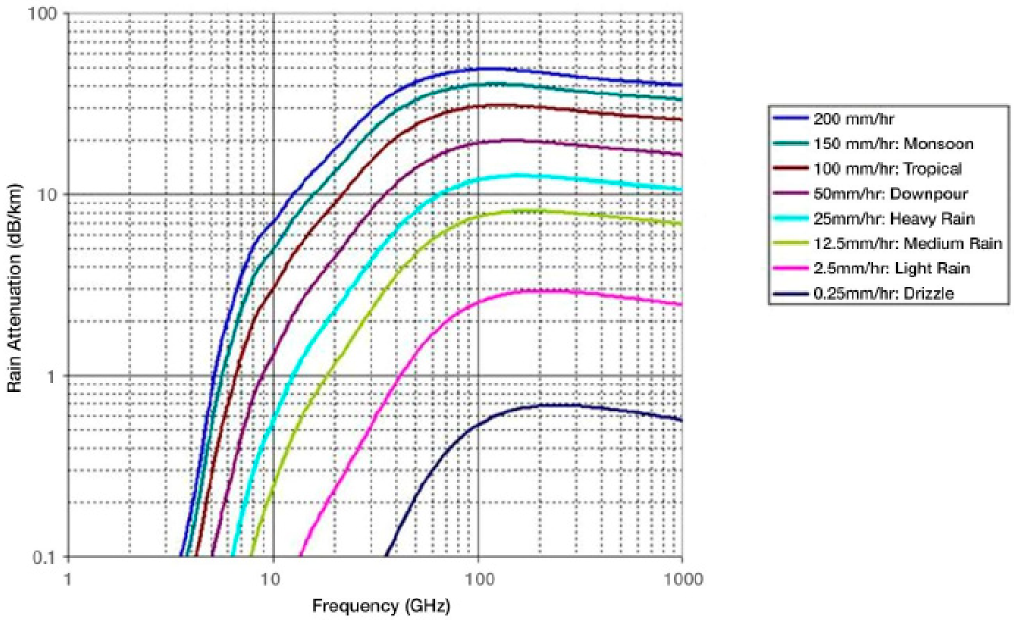


Figure 2: Specific rain attenuation (dB/Km) frequency (GHz) and rain rate(ML/HR)

Types of rain modelling

The ITU-R methods for calculating rain fade is as described:

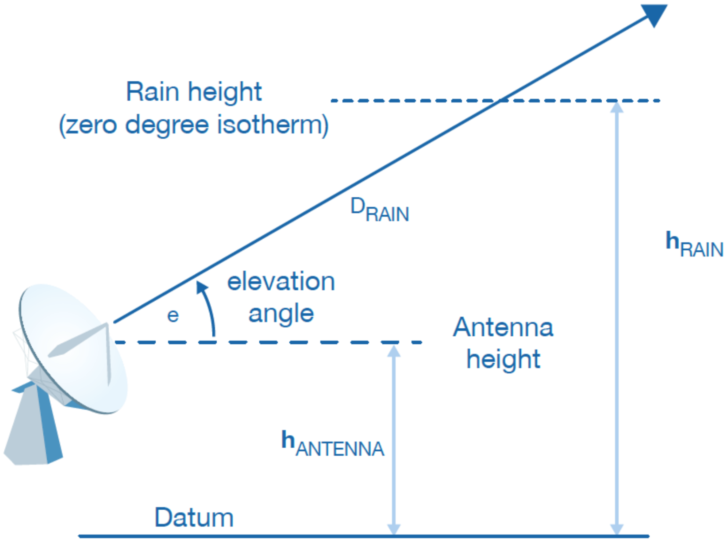
Rain fade varies with frequency, location, polarisation and rainfall rate. The depth of fade in dB can be calculated from:

$L_{RAIN} = Y_R D_{RAIN}$

Where:
L_{RAIN} is the rain loss in dB
R is the specific attenuation (dB/km)
D_{RAIN} is the path length through the troposphere in km,

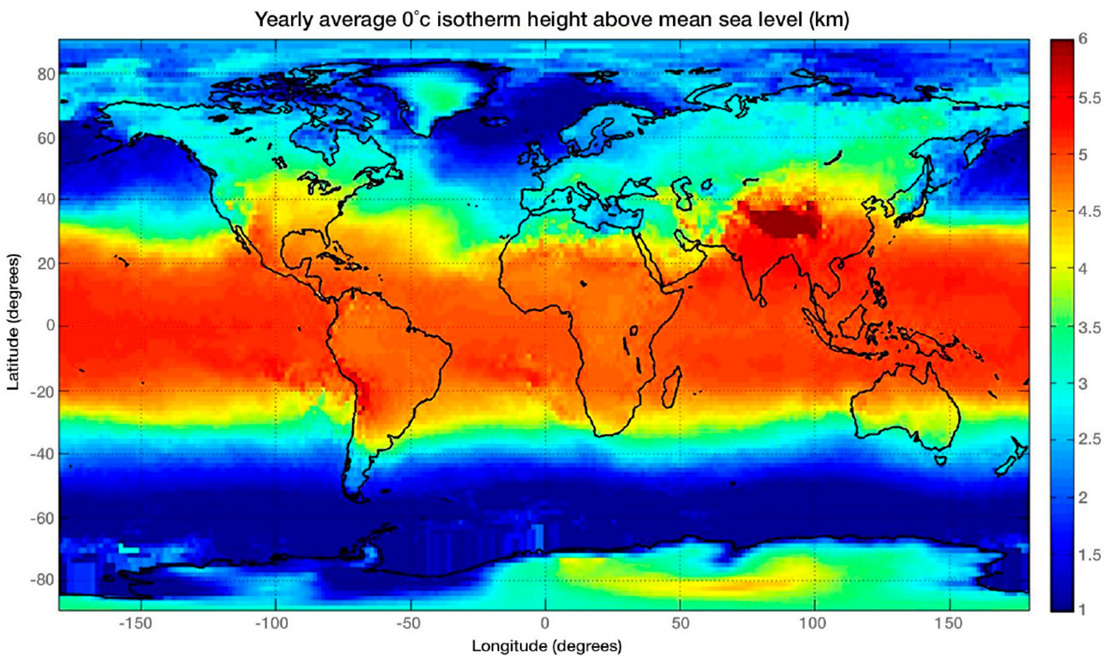
To calculate the rain attenuation, we need to know:

- Latitude and longitude of the earth station to within a degree
- Altitude of the station in km (hANTENNA)
- The frequency of operation (20GHz for receive, 30 GHz for transmit at Ka-band)
- The polarisation of the signal (typically circular for Ka-band services)
- The required availability of the satellite circuit



To calculate the rain attenuation, we need to know:

D_{RAIN} can be calculated from simple trigonometry from the above diagram.
$D_{RAIN} = (h_{RAIN} - h_{ANTENNA}) / Sin(e)$
This implies knowledge of the rain height h_{RAIN}.
Rain height at a given location is determined by using ITU-R Recommendation P.839-4 where the mean annual rain height above sea level (h_{RAIN}) may be obtained from the 0°C isotherm as:
$h_{RAIN} = h_0 + 0.36$ km
And h_0 can be found from the map below



In South Africa, for example, the latitude is between 21 and 34 degrees (as symbol) South, h_R is in the range of 4 to 5km Specific attenuation is calculated by using ITU-R P.838-3 method:
$Y_R = kR^a$
Where the rainfall rate R and the coefficients k and a are given in ITU-R P.837-6 (02/2012).

According to all studies and internationally agreed models, the single most important parameter that defines rain attenuation is the rainfall rate R (mm/h). Based on this parameter (derived from 40 years of data from the European Centre of Medium-Range Weather Forecast) contours can be defined based on the proportion of time (availability) that the rain rate exceeds a given rate. See Figure 3 for Africa.

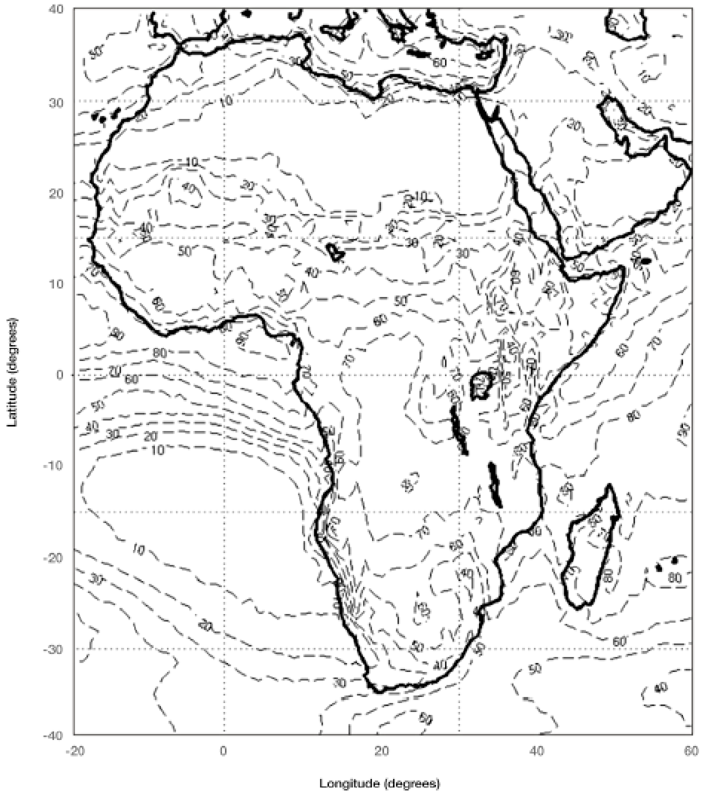


Figure 3: Rain rate (MM/H) exceeded for 0.01% of the average year

South Africa is covered by contours for 0.01% (= 53 mins/year the rainfall rate exceeds the contour value) ranging from 20 mm/h on the west coast to over 50 mm/h in the NE of the country. Table 1 shows the specific fade (total Atmospheric Attenuation) at various availabilities for Ka uplink and downlink frequencies for various locations looking towards the HYLAS 2 satellite
(at 31°E).

Location	Downlink (20GHz) Atmos Attn / dB						
	99.50%	99.60%	99.70%	99.80%	99.90%	99.95%	99.99%
Cape Town	1.44	1.73	2.07	2.65	3.78	5.41	11.00
Johannesburg	2.73	3.17	3.80	4.82	6.95	9.62	17.92
Durban	2.98	3.44	4.11	5.21	7.52	10.48	19.88
Bloemfontein	2.85	3.29	3.94	4.99	7.21	10.04	19.01

Table 1: Downlink atmospheric attenuation (dB) at different availabilities

Location	Uplink (30GHz) Atmos Attn / dB						
	99.50%	99.60%	99.70%	99.80%	99.90%	99.95%	99.99%
Cape Town	3.17	3.64	4.33	5.47	7.94	11.13	21.55
Johannesburg	6.02	6.95	8.27	10.35	14.62	19.82	35.16
Durban	6.70	7.69	9.10	11.37	16.09	21.93	39.57
Bloemfontein	6.28	7.23	8.57	10.72	15.17	20.66	37.18

Table 2: Uplink atmospheric attenuation (dB) at different availabilities

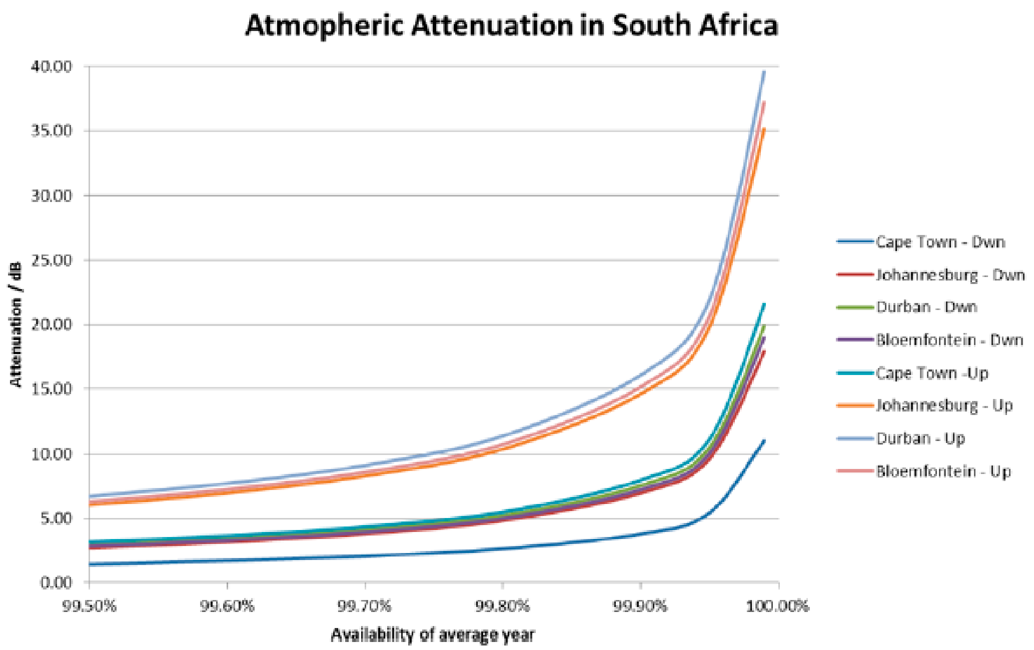


Figure 4: Atmospheric attenuation versus availability of average year

The graph above clearly shows how the attenuation due to rain fade rises exponentially at high availability, the so-called "rain fade problem for Ka-band". However, these deep rain fade events associated with high rain rates are usually the result of individual storm cells. These are typically only a few kilometres in size and, as a result, they are very localised. This explains why the fades are typically of short duration, as the storm cell tends to be moving quite quickly and pass through the field of view in a few minutes (typically 5 to 10 minutes).

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