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1 Scope

This document describes the uplink/downlink channel frequency used by Ka-band satellite channels in order to highlight the following issues:

1. How the carrier numbering needs to be extended to address this new spectrum and specific pairing?
2. How the estimation on DL can be used for the UL (atmospheric effect as well as frequency error) without channel reciprocity?
3. What procedures may be impacted (power control, modulation/coding mode selection, etc.)?

2 Satellite Communications bandwidths in Ka-band

The Ka-band for satellite communications commonly include 17.3 GHz-21.2 GHz, and 27.5 GHz – 31.0GHz. Global and regional spectrum allocations are made by International Telecommunications Union (ITU) and implemented by member states.

The bands 17.3 GHz – 21.2 GHz and 27.5 GHz – 31.0 GHz band, are allocated Fixed Satellite Services and Mobile Satellite Services, among other services (i.e., fixed and mobile services). They may also be shared by GEO and NGSO. Some parts may also be set aside for Military/Government use. The details vary by region or by country.

The Ka-band frequencies are generally circular polarized (CP). Both Left-hand CP and Right-hand CP can be used. More often than not, service downlink tends to be in the 17.3 GHz-21.2 GHz band to take advantage of the better propagation characteristics of the lower frequency, saving power requirement for the satellites, whereas the service uplink is in the 27.5 GHz-31.0 GHz band. Typical bent-pipe satellites also need feeder links. For High-Throughput Satellites (HTS) with multiple service beams, many feeder links may share the same frequencies with spatial multiplexing, achieved by very high gain Gateway antennas pointing to selected, spatially separate locations. Depending on the satellite architecture, the feeder links may also use part of the Ka-band frequencies. Alternatively, they may use frequency bands outside the Ka-band allowing the service links to use the full complement of Ka-band frequencies.

3 Uplink and Downlink Frequency Separation and Frequency Reuse

Exactly which parts of the band can be used for service uplink, service downlink, gateway uplink, and gateway down link, respectively must follow rules in individual countries. Creative arrangements can be considered within the spectrum administration rules. For multi-beam satellites, a cellular-like reuse pattern is typically used taking advantages of both frequency separation and polarization isolation. Most common reuse factors are 3 or 4, when antenna pattern alone does not provide sufficient isolation between beams. Generally, Frequency Division Duplexing (FDD) is preferred due to the long round trip propagation delay. Service uplink and service downlink are separated by about 10 GHz. Coverage area of uplink and downlink beams are congruent. FDD is also preferred for NGSO, since the propagation delay changes quickly as the satellites move in and out of reach quickly for any user terminals, making it harder for TDD to perform efficiently.

4 Channel Numbering

To apply NR to these Ka frequency bands, new channel numbers consistent with the NR channel numbering scheme have to be added. Not only the NR channel numbering range needs to be extended to include the 27.5GHz-31.0 GHz band, the numbering scheme needs to be able to uniquely identify channels in the left-hand CP and right-hand CP of the same frequency channel. In addition, a numbering scheme uniquely identifying channels in the 17.3 GHz-21.2 GHz band with a scheme associating it with the channels in the 27.5GHz-31.0 GHz consistent with the scheme that pairs with uplink channel number and downlink channel number in NR FDD mode needs to be developed.

5 Channel Estimation

Transmit channel estimation for Time Division Duplexing (TDD) systems is straightforward. By reciprocity, impairment measured from the received signal can be used directly as the estimate for the transmit channel. For FDD systems in frequency selective channels, however, transmit and receive signals are sent in different frequencies, therefore transmit and receive channels may be quite different. The major impairments for the Ka-band satellite channel is caused by atmospheric attenuation and Doppler frequency shift. This is very different from the terrestrial communication in which multipath fading dominates the impairments. Even when separated by about 10 GHz, the rain attenuation between transmit and receive frequencies are generally correlated. Based on decades of measurements, it is possible to use the amount of rain attenuation experienced in the 17.3-21.2 GHz band to estimate the attenuation in the 27.5-31.0 GHz band and vice versa using a translation table derived from empirical formulas based on measurements. An example of such formula recommended by ITU-R P.618-12 Section 2.2.1.3.2 is shown in the Annex. Also, since the path length going through the atmosphere is much longer than typically anticipated by the terrestrial links, the range for power control adjustments and modulation coding selection may have to be extended. Similarly, the Doppler frequency shift needs to be scaled from measurements from the received signal by the ratio of the frequencies between transmit and receive signal. This is no different than what is required for terrestrial applications, except the value for such compensation may have a much larger range.

The translation can be made more accurate if effects other than rain attenuation, such as change in receive G/T in rain, power variation on the transmit side can be obtained separately. Alternatively, some margin may have to be allowed.

6 Conclusion

The NR channel numbering system needs to be extended to include the 27.5 GHz-31.0 GHz band. Due to pairing of the uplink with the downlink in the Ka-band satellite channel, it also needs to include the 17.3 GHz-21.2 GHz band.

It seems that the wide separation of the uplink and downlink bands used by Ka-band satellite systems will require a translation of atmospheric attenuation from measurement of the received signal before applying to the transmit power compensation and modulation and coding selection, even though no changes are needed to the basic algorithms. The parameter range needs to be evaluated. Similarly, Doppler compensation, the parameter range may need to be extended.

Annex. ITU-R P.618-12 Recommendation

The following section has often been used to scale rain attenuation measured in one frequency to the same in another frequency of the same path.

2.2.1.3.2 Long-term frequency scaling of rain attenuation statistics

If reliable attenuation data measured at one frequency are available, the following empirical formula giving an attenuation ratio directly as a function of frequency and attenuation may be applied for frequency scaling on the same path in the frequency range 7 to 55 GHz:

$$A_2 = A_1(\varphi_2 / \varphi_1)^{1-H(\varphi_1, \varphi_2, A_1)} \quad (23)$$

where:

$$\varphi(f) = \frac{f^2}{1 + 10^{-4} f^2} \quad (24a)$$

$$H(\varphi_1, \varphi_2, A_1) = 1.12 \times 10^{-3} (\varphi_2 / \varphi_1)^{0.5} (\varphi_1 A_1)^{0.55} \quad (24b)$$

A_1 and A_2 are the equiprobable values of the excess rain attenuation at frequencies f_1 and f_2 (GHz), respectively.

Frequency scaling of attenuation from reliable long-term measured attenuation data, rather than long-term measured rain data, is preferred.