WHITE PAPER

Testing Satellite Communications for 5G Networks

Introduction

Recent developments in 3GPP have brought into great attention the need to test satellites against fading conditions. 5G NTN (non-terrestrial network) introduces a satellite component to traditional land mobile cellular 5G systems. In September 2020, 3GPP released TR 38.811, entitled "Study on New Radio (NR) to support non-terrestrial networks.[1]" It details the channel models used in chapter 6 of 3GPP TR38.913. The models are well detailed for large-scale parameters such as shadowing, outdoor-to-indoor (O2I) loss, clutter loss, path loss, and small-scale parameters such as with fading. The models used for fading are derived from an earlier specification, TR 38.901 V16.1.0, entitled 'Study on channel model for frequencies from 0.5 to 100 GHz'[2], and use proper scaling factors. Thus, it is evident that fading needs to be incorporated into testing 5G NTN.

Even though the fading models defined in TR 38.811 are based on TR 38.901 and therefore represent the best understanding of radio propagation, it is worth calling out a few issues specific to testing satellite systems. We discuss these next.

A Test Matrix for Satellite Implementations

The purpose of testing is to find malfunctions, bugs, or any other undesired performance of the radio system in question. Satellite communications are no different. If the test system is unable to reveal design flaws, no matter how realistic it might be, it is a wasted investment. Instead of just emulating channel models from the new 3GPP specifications, it is better to consider what might make the satellite transceiver fail and find models that stress those parameters in the lab. Once these stressed parameters are found, channel models are swept one by one, keeping others fixed to examine one parameter at a time and see how it affects transceiver performance. As an outcome, a systematic testing sequence is created, which can be automated and run 24x7.

Satellite communications come in many shapes and forms. A GEO (geostationary orbit) satellite propagation environment differs considerably from an LEO (low Earth orbit) satellite propagation environment. Thus, it is very important to understand which category of 5G NTN will be tested and then determine the above-mentioned systematic testing sequences. However, we can outline the idea behind the theory and then the user can select which parameters to vary in testing based on the satellite system in question.

1 3GPP TR 38.811 V15.4.0, 'Study on New Radio (NR) to support non-terrestrial networks', Sept. 2020
2 3GPP TR 38.901 V16.1.0, 'Study on channel model for frequencies from 0.5 to 100 GHz', Dec. 2019

Let us assume that we need to test a 5G NTN LEO implementation. By default, the fading characteristics and large-scale fading are taken from TR 38.811. However, to make full use of the valuable channel modeling work included in that specification, the models need variability in the parameters that matter most. Let us examine that. First, satellite speed is very fast, causing a large Doppler shift. Second, the satellite transmitter is very far away (compared to terrestrial links), thus bulk delay becomes large. In addition, it is known that propagation attenuation is also large, thus the signal to noise ratio is small. These three parameters define a test cube, a parameter space, that needs to be varied with the proper channel models. Thus, we sample the parameters one by one in this test cube. Figure 1 represents the parameter space and sampling.

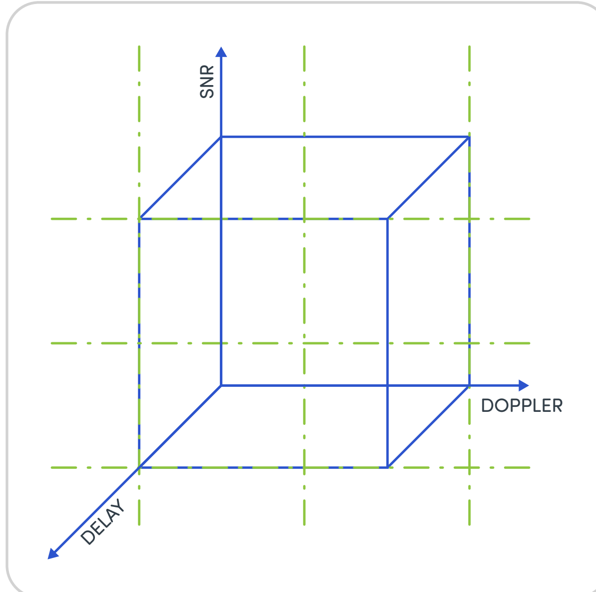

Figure 1: Test cube (blue) in 3D (Doppler, Delay, SNR) co-ordinate system and sampling (green)

The dimensions of the test cube are selected from either a) the environment or b) the satellite system in question, whichever is larger. This will lead to a systematic testing table that efficiently stresses the satellite transceiver to prevent field escapes.

An example of such a test sequence is in the table below. The user can add more key performance indicators (KPIs) based on needs, but since the fading equipment is programmable, we are able to make scripts that execute large quantities of tests in a short amount of time. The Y axis lists what we measure, and the X axis lists the environmental conditions against which the KPIs are measured.

Measured values		Environment									
		Large Doppler					Large Delay				
Radio system	KPI	CDL-A	CDL-B	CDL-C	CDL-D	SNR	CDL-A	CDL-B	CDL-C	CDL-D	SNR
LEO sat com	Tput					-5					-5
						0					0
						5					5
						10					10
						15					15
						20					20

Table 1: Example test matrix for an LEO satellite application

Preparing for Future Complexities

Future networks will become a complex mix of various radio systems. Besides horizontal expansion (e.g., coverage to maritime, deserts, etc.), we also have vertical expansion of the network, as shown in Figure 2.

The network will become very complex and the number of interactions between network elements and users will grow exponentially. Accordingly, testing this kind of network is also very complex and leads to extremely costly test solutions if only brute force is used.

Instead, we should always look for ways to simplify testing to have a) traceability and b) cost-efficient testing methods. Spirent believes in 'testing what matters' rather than trying to mimic all possible connections and radios. However, we must maintain the topology of the network, even in the testing subset. Figure 2 reveals that network topologies are not necessarily cellular type, but rather MESH type topologies between all nodes in the network. MESH topologies require a high radio link capacity; thus it is mandatory to incorporate high delay and large Doppler effects. When thinking about satellite testing, one key question is to determine how many radio links are supported by the test instrument under these conditions.

As said earlier, it is more efficient to focus on stressing the right attributes of the radio system. One focus of the 3GPP working group was to examine the FDD/TDD co-existence issue, which is major issue in NTN[4]. That is, we have two different duplex systems. Thus, in its simplest form, this is tested using one terrestrial link and one satellite link and performing a handover between them, as in Figure 3.

Thus, instead of trying to encapsulate the whole network into a test system, it is better to consider what is critical to system performance and perform tests such that the critical attribute is stressed.

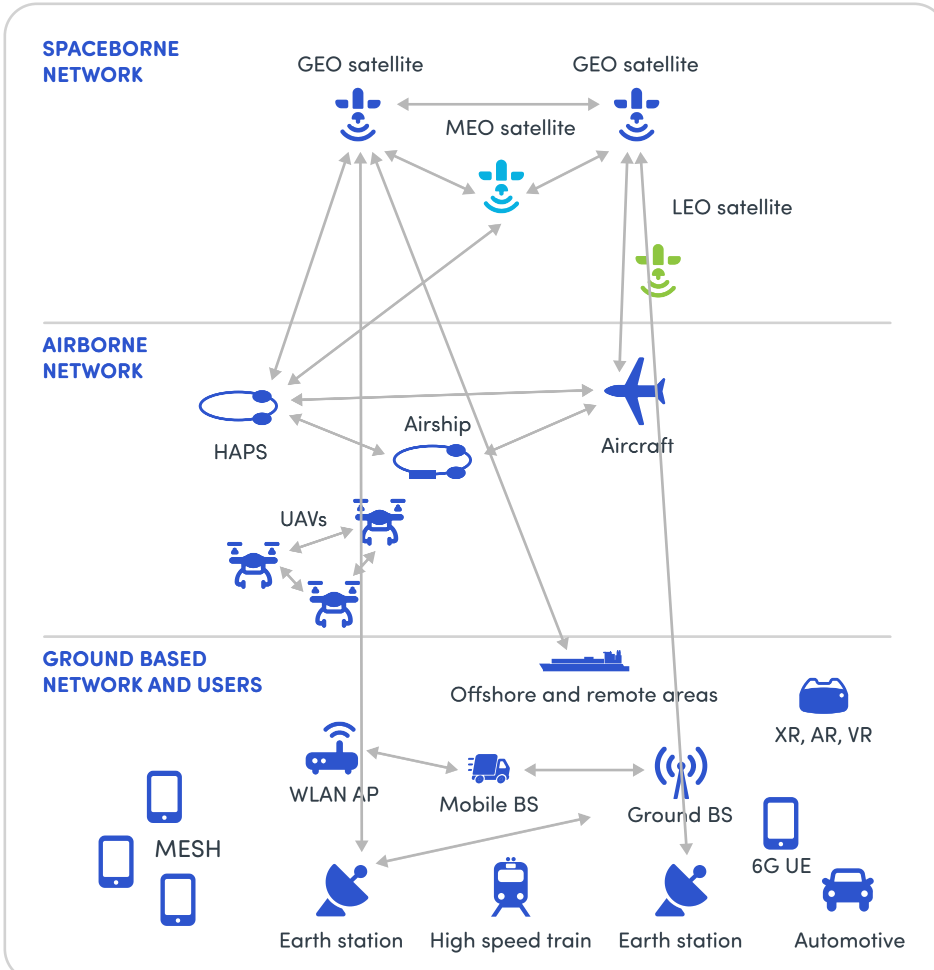

Figure 2: Vertical expansion of the network[3].

Figure 3: Co-existence test setup.

3 Nandana Rajatheva, et.al., 'White Paper on Broadband Connectivity in 6G', 6G Wireless Summit 2020, 30th April, 2020
4 R4-2015907, 3GPP, 'NTN: coexistence studies', 3GPP TSG-RAN WG4 Meeting #97-e, Nov. 2020, Ericsson

This simplistic test system will answer the question as to why the radio fails and give a simpler answer, rather than trying to capture all signal space into the test plan. Handover scenarios can be created using fading equipment, e.g., using a saw tooth power profile, Figure 4.

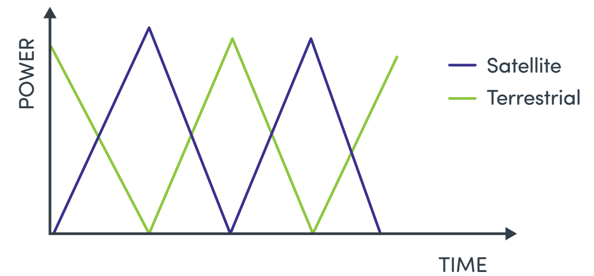

Figure 4: Creating a handover between terrestrial and satellite links by power variation.

The idea behind Figure 4 is very simple. We control the received power from satellite and terrestrial links with fading equipment such that when the receiver power of the terrestrial link is in peak, the power from satellite link is minimum and vice versa. This initiates the handover process and the receiver camps either on the satellite or terrestrial link. That allows us to measure, e.g., handover success rate and therefore examine co-existence in a simplified test system.

This will complement the testing table to also consider a) joint delay and Doppler, b) comparison to terrestrial link (i.e., user experience) and c) co-existence into the following test matrix.

Measured values		Environment														
		Large Doppler					Large Delay					Large Delay & Large Doppler				
Radio system	KPI	CDL-A	CDL-B	CDL-C	CDL-D	SNR	CDL-A	CDL-B	CDL-C	CDL-D	SNR	CDL-A	CDL-B	CDL-C	CDL-D	SNR
LEO sat com	Tput					-5					-5					-5
						0					0					0
						5					5					5
						10					10					10
						15					15					15
						20					20					20
5G Terrestrial link	Tput					-5					-5					-5
						0					0					0
						5					5					5
						10					10					10
						15					15					15
						20					20					20
Co-existence	HO success rate					Saw tooth					Saw tooth					Saw tooth

Table 2: Example test matrix for satellite/terrestrial handovers

About Spirent

Spirent Communications (LSE: SPT) is a global leader with deep expertise and decades of experience in testing, assurance, analytics and security, serving developers, service providers, and enterprise networks. We help bring clarity to increasingly complex technological and business challenges. Spirent's customers have made a promise to their customers to deliver superior performance. Spirent assures that those promises are fulfilled.

For more information visit: www.spirent.com

Testing Efficiency is Key

In conclusion, we propose testing against environmental conditions that can be traced back to specific radio channel parameters, starting from transceiver design. We also propose simplifying the test plan to 'test what matters' for the specific satellite category and application, rather than trying to encapsulate the entire network. In this way, key edge parameters become the primary focus and the full breadth of testing can be minimized for a more cost-effective solution.

Spirent's state-of-the-art channel emulation solutions can replicate the comprehensive impairment and spatial conditions of even the most complex wireless channels, making it possible to conduct repeatable lab tests that have real-world relevance, lower costs, and improve test program outcomes while minimizing risk.

The Spirent Vertex Channel Emulator provides the modularity, flexibility and high density needed for a myriad of challenging test configurations, while the graphical user interface of the Advanced Channel Modeling software simplifies the design of your propagation scenarios and allows creation of downloadable 3D channel models. Vertex offers unparalleled capacity in the number of radio links required to support satellite MESH topologies and network level testing. This is due to the unique real-time processing of the instrument; that is, the signal is not buffered to the internal memory to create long delays.

A trusted provider for over 25 years, Spirent has led the definition of complex fading with multiple radios spanning several generations of mobile technologies. Our team of world-renowned experts are here to help. To learn more about channel emulation for both terrestrial and satellite applications, contact us.

Americas 1-800-SPIRENT
+1-800-774-7368 | sales@spirent.com

Europe and the Middle East
+44 (0) 1293 767979 | emeainfo@spirent.com

Asia and the Pacific
+86-10-8518-2539 | salesasia@spirent.com

spirent™