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# Channel measurements and models for 6G: current status and future outlook



**Key words:** Channel measurements; Channel models; Sixth generation; Terahertz; Industrial Internet of Things; Space-air-ground integrated network; Machine learning

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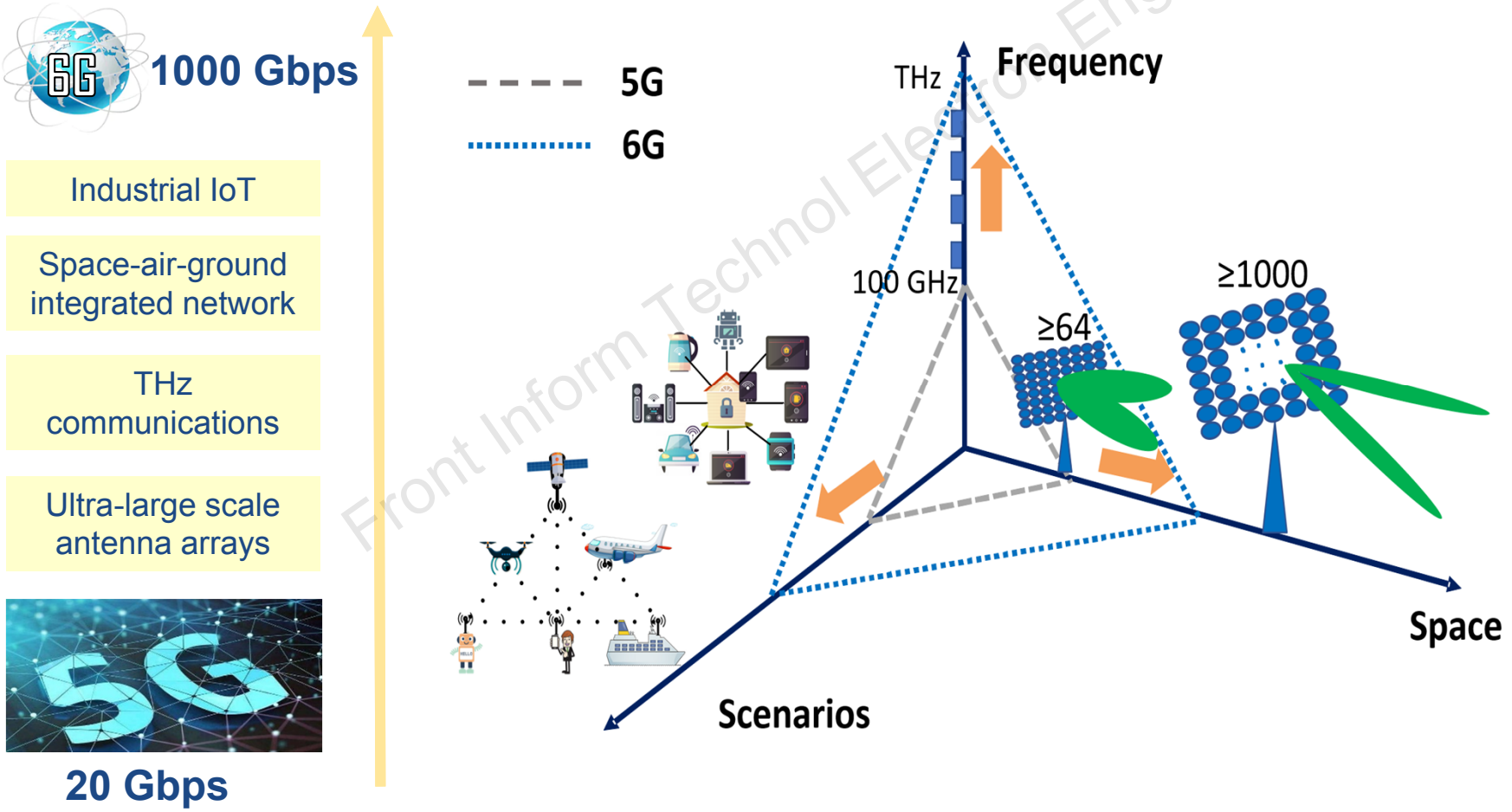
# 6G global progress

- With recent commercialization of 5G worldwide, some countries and organizations have started 6G research.

| Date | Event |
|---|---|
| 2017.9 | The European Union started projects to research Terahertz (THz) communication, visible light communication, and D band radio for Beyond 5G (B5G) |
| 2018.7 | The ITU-T Focus Group Technologies for Network 2030 (FG NET-2030) was established, which intends to study the capabilities of networks for the year 2030 and beyond |
| 2019.3 | The Federal Communications Commission (FCC) opened up experimental spectrum licenses for 6G |
| 2019.7 | Korea Telecom (KT) and Seoul National University would cooperate in developing and standardizing technologies for 6G telecommunications |
| 2019.11 | The Ministry of Science and Technology announced that China has established a national research and development group for 6G |

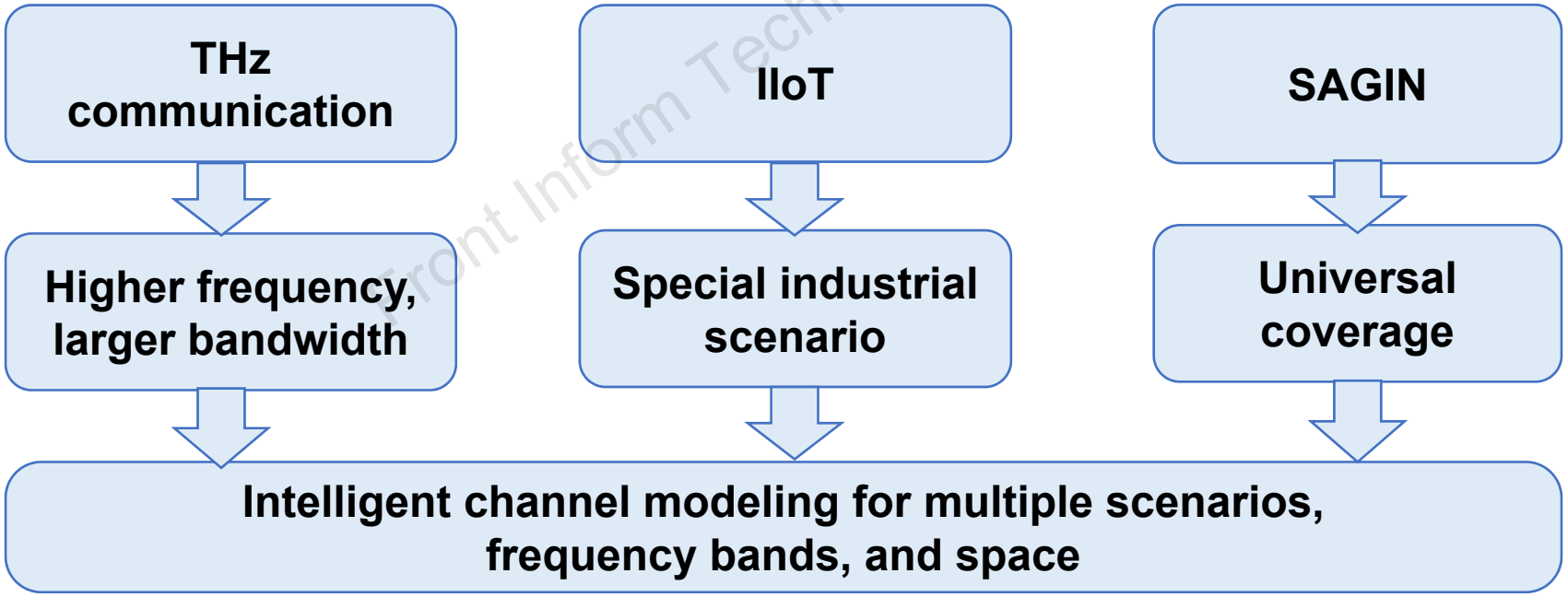
# Tendency and challenges

- 6G will expand in three dimensions, i.e., space, frequency, and scenarios; thus, channel prosperity becomes more versatile and accurate modeling with low complexity more difficult.



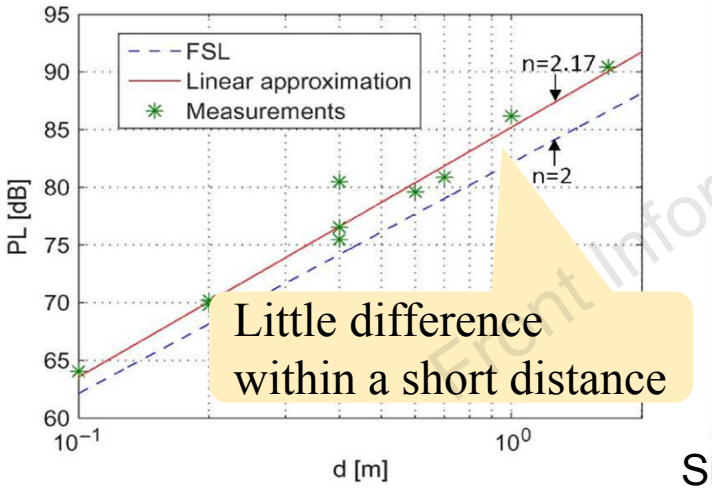
# Motivation

- The study on channel property and modeling is fundamental and vital for 6G research and development, especially considering the new applications and techniques, including THz communication, IIoT, and SAGIN in 6G.
- Moreover, combining recent progress on machine learning, intelligent channel modeling is essential for supporting the multiple scenarios, frequency and space dimension expansion for 6G.

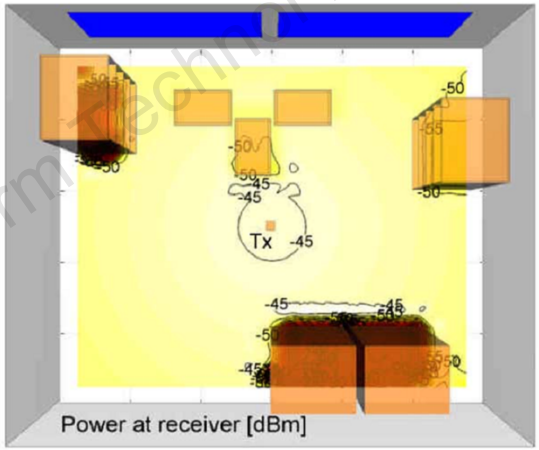


# 1) THz channel measurements and modeling

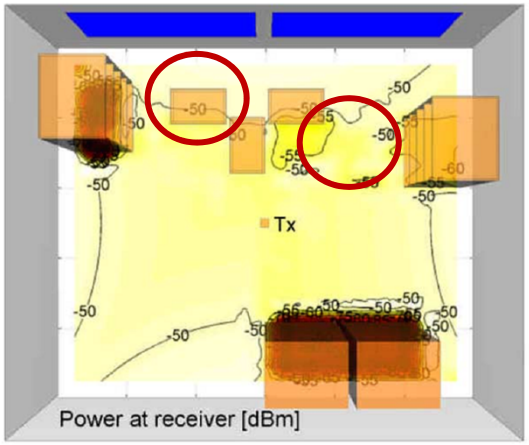
- Most channel measurements were conducted using the THz-TDS or VNA platform.
- Study on the THz channel focuses on the propagation mechanism on different materials and traditional channel parameters, like path loss, delay, and spatial characteristics [7-8].




Indoor path loss (300-310 GHz)




Single hop specular reflection



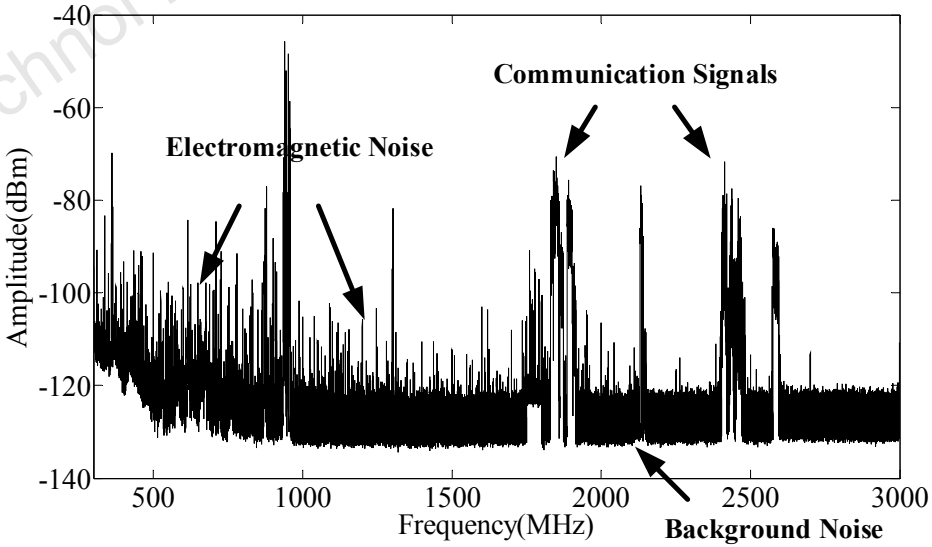

Double hop specular reflection

Indoor channel simulation using ray-tracing (350 GHz)

# 2) IIoT channel measurements and modeling

- Industrial scenarios are larger and more complex than traditional indoor scenarios. Scatterers with high reflection coefficients make small-scale fading change quickly.
- Noise and interference have more significant effects on channel measurements and modeling in industrial scenarios [9].

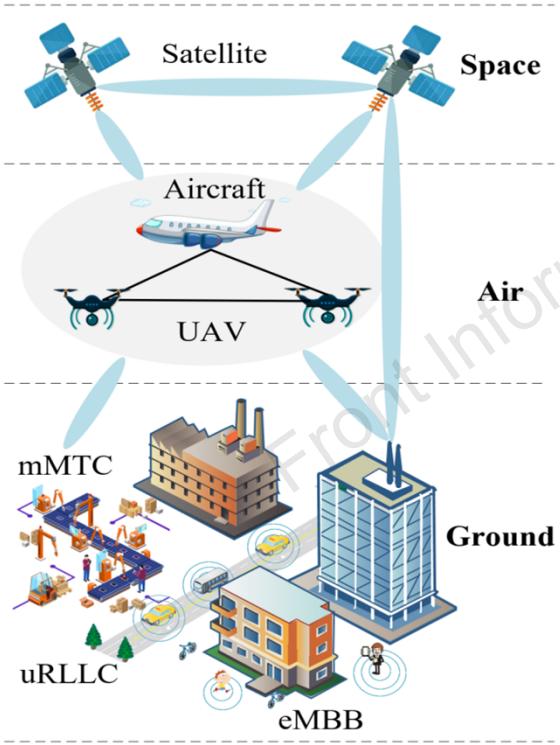

Industrial scenario



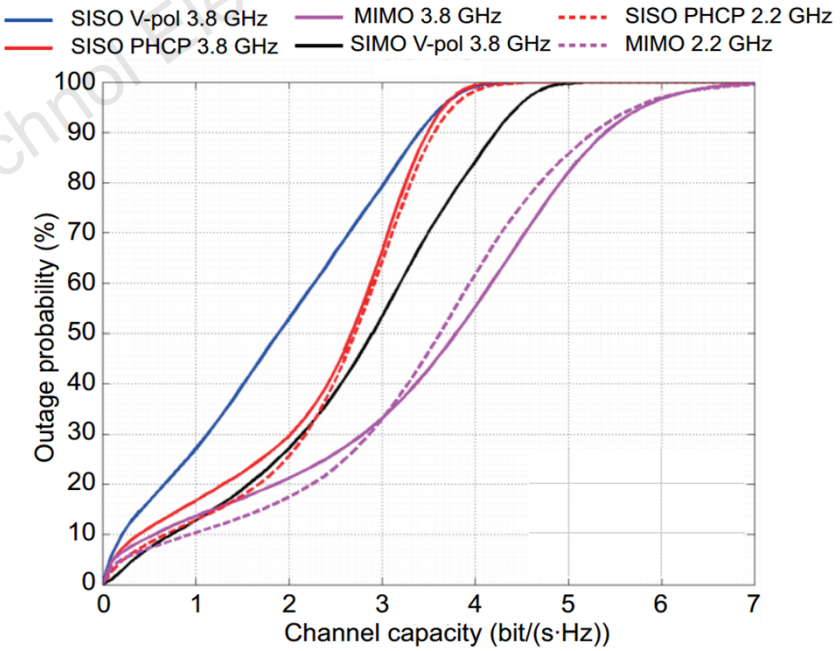

Noise frequency distributions in a welding workshop

# 3) SAGIN channel measurements and modeling

- SAGIN channel covers an extra large height range, and channel characteristics are dependent on the height.
- A large number of channel measurements focus on either one network segment, e.g., space, air, or ground, or integration of two of the three network segments [10].



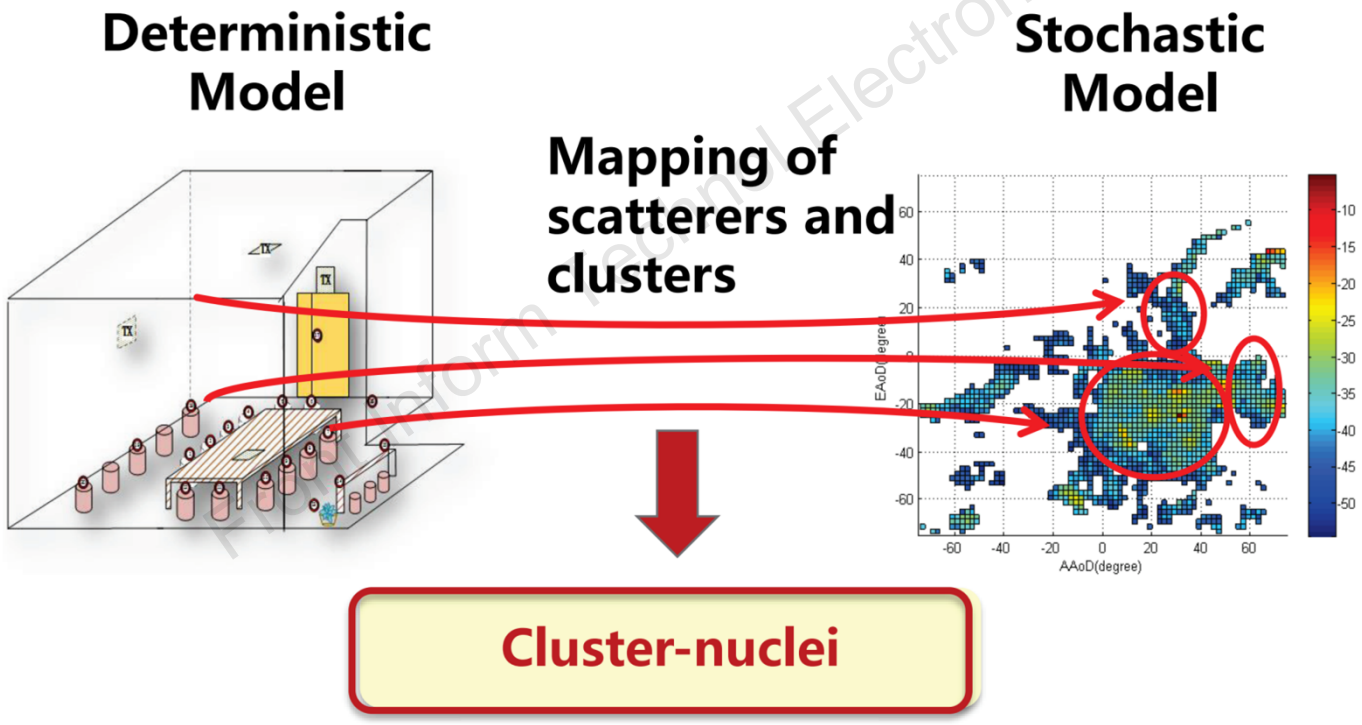

The diagram of SAGIN




Channel capacity results in space-to-ground communication scenarios

# 4) Intelligent channel modeling

- The cluster-nuclei based channel model combines computer vision and graphic science, and reveals the mapping relationship between scatterers and clusters [1,6].




The mechanism of cluster-nuclei

# 4) Intelligent channel modeling

- An intelligent channel model should be able to predict the channel response automatically based on rules hidden in the big volume of channel data [1,2,6].

**Input**

Wireless propagation environment

**Output**


Channel fading predicted by intelligent channel modeling

# Future outlook

| B5G/6G channel research | Outlook |
| --- | --- |
| THz channel | • Reliable channel measurement scheme<br>• Effects of molecular absorption on propagation fading<br>• Complete space-time-frequency and non-stationary channel characteristics |
| IIoT channel | • Effects of shadowing from scatterers<br>• Channel correlation between terminals<br>• Modeling noise and interference |
| SAGIN channel | • Differences in channel characteristics across space<br>• General channel model for different space<br>• Channel characteristics when using new communication technologies |
| Intelligent channel modeling | • The variation laws of cluster-nuclei characteristics<br>• The mapping relationship between cluster-nuclei and large span scatterers<br>• A high-precision and low-complexity channel modeling method under multi-dimensional non-stationary and large-span scales conditions |

# References


[1] Zhang, Jianhua. “The interdisciplinary research of big data and wireless channel: A cluster-nuclei based channel model.” *China communications* 13.2 (2016):14-26.

[2] Ma, Xiaochuan, et al. “A PCA-based modeling method for wireless MIMO channel.” 2017 IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS). IEEE, 2017.

[3] Li, Yupeng, et al. “Clustering analysis in the wireless propagation channel with a variational Gaussian mixture model.” *IEEE Transactions on Big Data* (2018).

[4] Zhang, Jianhua, et al. “3-D MIMO: How much does it meet our expectations observed from channel measurements?” *IEEE Journal on Selected Areas in Communications* 35.8 (2017):1887-1903.

[5] Zhang, Jianhua, et al. “3D MIMO for 5G NR: Several observations from 32 to massive 256 antennas based on channel measurement.” *IEEE Communications Magazine* 56.3 (2018):62-70.

[6] Li, Wei, et al. “The way to apply machine learning to IoT driven wireless network from channel perspective.” *China Communications* 16.1 (2019):148-164.

[7] Priebe, Sebastian, et al. “Channel and propagation measurements at 300 GHz.” *IEEE Transactions on Antennas and Propagation* 59.5 (2011):1688-1698.

[8] Piesiewicz, Radoslaw, et al. “Performance analysis of future multigigabit wireless communication systems at THz frequencies with highly directive antennas in realistic indoor environments.” *IEEE Journal of Selected Topics in Quantum Electronics* 14.2 (2008):421-430.

[9] Ze, Yuan, et al. “Measurement based Characterization of Electromagnetic Noise for Industrial Internet of Things.” *Procedia Computer Science* 147 (2019):145-150.

[10] Lacoste, Frédéric, et al. “MISO and SIMO measurements of the Land Mobile Satellite propagation channel at S-band.” Proc 4th European Conference on Antennas and Propagation. IEEE, 2010.