What Propagation Mode did you use and Why?

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Referring to the NZ VHF/UHF/SHF 2024 Records:
https://zl2vh.nz/assets/pdf/dx-records/nzrecords2024.pdf

The far right column lists the Propagation Mode or Path associated with any DX record listed.

Look at the bottom of the page. Notes section **7)** and **8)**

7) Propagation Modes: Line Of Sight (LOS), Tropo Duct (TD), Sporadic E (TD/E), Tropo Scatter (TS), Meteor Scatter (MS), F2-Layer (F2) Earth Moon Earth (EME), Trans Equatorial Propagation (TEP), Precipitation Scatter (PS), Field Aligned Irregularities (FAI), Aurora and Aurora E (A/AE), E-Layer Back Scatter (EBS), F-Layer Refraction, Diffraction, Side Scatter (FR/FD/FS), Knife Edge Diffraction (KED), Solid Object Refraction (SOR), D/E-Layer Ionospheric Forward Scatter.

8) Sporadic E is a propagation mode that is difficult to verify and is therefore listed as a TD/E unless weather conditions across the path rule out TD and then E-Skip is the only possible mode.

I was recently asked to explain how an operator knows what mode to choose when claiming a DX record and what was going on during recent Oceania 10 m and 6 m DX activity.
The following should help to explain with an emphasise on E-Layer propagation experienced during the December 2020 and June / July 2021 periods and reported in Break-In VHF Scene column.
Bob ZL1RS has also worked some Long Path (LP) QSO's that exceeded expected LP distances via multi hop propagation that is further than the longest expected path.
In 2014 ZL4AX worked MA0BSM via TEP+Es+F propagation paths.
In March 2025 ZL1RS worked ZS4TX/6 via 11,000 kms F2 + 8.500 kms F2 + 7,000 kms TEP a round 26,500 kms distance. This QSO was via Scatter point distances and not a true Long path distance.

The Solar Flux Index (SFI) has been up and down during these periods and not having any influence over propagation apart from some HF bands.

The Hepburn DX Info https://dxinfocentre.com/tropo_aus.html was not indicating weather related propagation mainly influencing a Tropospheric Duct event.
This quote from the web page is what the Hepburn advises;
"*The areas noted in the forecast have the necessary atmospheric conditions to produce tropospheric bending of VHF, UHF and/or microwave radio waves. Tropospheric bending extends the range of radio & TV stations well beyond their normal limit and thus increases interference amongst stations as well.*"

The following article consists of my own observations and those of Emil Pocock W3EP.
Emil was a regular columnist for QST with "The world above 50 MHz" and involved with Region 1 DX records.
QST, CQ, UKSMG Six News Archives and RSGB articles I collected over the many years as NZART VHF/UHF/SHF Records Coordinator are referenced at the end of the article.
My hope is that this information I am passing forward helps DXers and record claimants.

There is a puzzling number of possibilities as in the Note 7) mentioned above yet some operators are able to identify in an instant the propagation mode or path of any signal with a good deal of apparent confidence. How does anyone tell the Meteor Scatter from Back Scatter, Aurora from Auroral E or distinguish among any other propagation mode?

These are no simple answers or secret methods. Those who are most proficient in this art have probably spent a good deal of time listening to a variety of signals under different conditions.
Although listening experience counts for a good deal, it is necessary to compare what you hear and observe with known characteristics of various propagation modes in order to make reasonable deductions. Most of the time, you can identify the propagation with reasonable assurance, but even the most experienced VHFers cannot be certain in every case.

There are occasions when no profile seems to fit well and experience is of little help either.
Often there are alternative plausible explanations such as the involvement of two propagation modes simultaneously, but sometimes the responsible propagation mode simply remains uncertain.

Operating frequency is a good place to start. Most propagation modes and paths affect only a particular range of frequencies and this characteristic provides the first diagnostic filter.
For the most common frequency span and distance ranges for each propagation mode see Table-1.

Table-1

Troposphere
Troposphere Scatter: 50 MHz to 300 GHz. Range 1 to 800 kms.
Troposphere Ducting: 50 MHz to 300 GHz. Range 100 to 4,000 kms.
Troposphere Precipitation Scatter: 10 GHz to 24 GHz. Range 5 to 400 kms.

E-Layer
D/E-Layer Ionospheric Scatter: 28 MHz to 144 MHz. Range 800 to 2,000 kms.
Meteor Scatter: 50 MHz to 432 MHz. Range 800 to 2,300 kms.
Field Aligned Irregularities: 50 MHz to 144 MHz. Range 100 to 2,300 kms.
E-Layer Back Scatter: 50 MHz to 144 MHz. Range 50 to 2,000 kms.
Sporadic E, E-Skip, E's: 28 MHz to 144 MHz. Range 500 to 2,300 kms.
Auroral-E: 50 MHz to 144 MHz. Range 500 to 5,000+kms.
Aurora: 50 MHz to 432 MHz. Range 50 to 2,300 kms.

F-Layer
F-Layer Refraction Skip F2: 28 MHz to 50 MHz. Range 2,000 to 20,000 kms.
F-Layer Back Scatter: 28 MHz to 50 MHz. Range 100 to 2,000 kms.
F-Layer Side Scatter: 28 MHz to 50 MHz. Range 2,000 to 6,000 kms.
Transequatorial Field-Aligned Irregularities FAI: 28 MHz to 220 MHz. Range 4,000 to 8,000 kms.

Refraction and Diffraction
Earth-Moon-Earth EME, Moonbounce: 50 MHz to 300 GHz. Range 50 to 20,000 kms
Knife-Edge Diffraction: 50 MHz to 300 GHz. Range 10-600 kms.
Solid-Object Reflection: 28 MHz to 300 GHz. Range 10 to 800 kms.

Table-2

Propagation diagnosis profile

Each propagation mode has distinctive characteristics or profile.
Frequency: Operating frequency, conditions on adjacent bands.
Signal: Strength, Fading characteristics, Quality.
Temporary Status: Duration of the opening, Time of the day, Season, Solar cycle position.
Weather and Solar Conditions: Weather along the signal path, Solar activity (SFI), Geomagnetic activity.
Equipment: Antenna gain, Polarisation, Beam heading, TX Power, TX mode, RX Characteristics.

These profiles can be compared with what you hear to come to some justification conclusion.
In some rare instances, frequencies outside the normal range might be affected but these cases must be evaluated carefully and in light of all other observations.

Check the higher and lower bands at the same time to get some sense of what range of frequencies are being affected. Perhaps you hear some stations on 144 MHz booming in from 1500 kms away and suspect Sporadic E. Check for activity on 50 MHz as Sporadic E affects lower frequencies first, then higher ones. Sporadic E on 144 MHz almost certainly means there is a Sporadic E on 50 MHz as well.
If you hear nothing on 6 m and no one else is reporting E skip on the band, it is probably not Sporadic E you are hearing on 144 MHz. Check 432 MHz. You hear more strong stations!
The resulting frequency profile-strong signals at a great distance on 144 MHz and 432 MHz, but nothing on 50 MHz, strongly points to tropospheric ducting, not Sporadic E.

Signal strength and quality also provides valuable indications.
Signals propagated by Sporadic E, for example, can be exceedingly strong, but may come and go over short time periods and fading can be severe. Signals propagated by Aurora have a characteristic distortion variously described as a buzz or broad mushy hiss that, once heard, is easy to identify again unmistakable Aurora. The various scatter modes and FAI also impose distinctive distortions on signals.
Indeed most propagation modes have characteristic profiles of signal strength, quality and fading that are often nearly conclusive by themselves.

Physics and geometry also puts limits on the minimum and maximum distances over which radio signals can be propagated by various modes.
The above Table-1 provides a general guide to normal distance limits.
Path location and orientation are also important, as most propagation modes are limited to certain zones of the earth or are more common over some regions than others.
Auroral E is normally confined to auroral zones, and signals propagated by E-Layer FAI always create radio paths skewed to the south in the Southern hemisphere.
Other propagation modes have strict orientation requirements.
Signals propagated by Transequatorial FAI must be perpendicular to the geomagnetic equator.
Temporary status considerations, including time of day, season and duration of openings also provide valuable clues. D/E-Layer forward scatter is most predominant around noon local time and is unlikely at night. In contrast, Auroral E is almost exclusively, a night time phenomenon.

Sporadic E appears to be seasonal and even evident during equinox periods.
50 MHz and above F-layer propagation is possible during peaks of solar cycles where the Solar Flux Index (SFI) is above 100.
Nearly all modes have favoured times of the day that can provide some clues about what propagation mechanism is more likely.

The weather over a VHF path can help determine if a tropospheric mode, such as ducting, is responsible or help rule such a possibility. Ducting is unlikely, for example, if thunderstorms appear anywhere along a signal path. Weather plays no known role nor provides reliable clues about any ionospheric conditions. Solar and geomagnetic activity provides reliable valuable indicators in case of suspected aurora, Auroral E and F-Layer propagation.

Equipment used can also provide useful information, especially when compared against signal strength. Weak signals may not be significant if participating stations ran low power, used simple antenna and were in unfavourable locations. Similarly, high power and large antenna are practically a requirement to make use of some propagation modes, like ionosphere forward scatter. Even transmission mode can be helpful. As a practical matter, it is unlikely that FM stations can really make effective use of aurora because of the distortion involved. Antenna gain and direction can also yield important clues, especially for identifying modes that have skewed paths.

Finally, some propagation modes usually appear only in association with another mode. FAI, for example, depends on the prior existence of a strong region of sporadic E. It would be usual for an FAI contact to take place without simultaneous reports of sporadic E, In some cases, the simultaneous appearance of two propagation modes are required to explain unusual contacts. Sporadic E sometimes serves this role by providing a strong link into the F-Layer or into transequatorial regions that would otherwise be unreachable. many unusual contacts that seem to fall outside the normal profiles of any single propagation mode may very well be due to a combination.

Mode-by-Mode

You can make your own identifications using the diagnostic indications in Table-2.
Note the frequency, signal strength and quality, path length, time of day, and other indicators of the signal you wish to identify. Compare the profile you derive with the known characteristics of each propagation mode. Read about the characteristics of various modes in any reliable radio handbook or guide to propagation. You may want to extend the list in Table-2 by adding additional indications as you learn about them. Ask more experienced operators to help identify what you are hearing, but be sure to ask them ***how do you know?***

Table-3:
Listed modes and a more detailed description of each.

Tropospheric Scatter: Tropo Scatter uses a weak, but reliable reflection obtained from the dust particles, clouds, and refractive index variations that occur in the atmosphere around 1 km to 15 kms above sea level. This mechanism can be used for reliable DX contacts over distances 1 to 800 kms.

Tropospheric Ducting: is a generic term used that can be any of four types of propagation.
1) N - Normal refraction.
2) B - Sub standard refraction.
3) R - Super refraction.
4) D - Ducting.

Refraction occurs normally during summer months due to an favourable refraction index in the lower atmospheric zones between 1 km to 7 kms. The refractive index is determined by temperature, pressure and the amount of water vapour (humidity) contained in the air.

Ducting is the premier mode for VHF/UHF/SHF DX. In this mode tropo refraction and ducting is where a troposphere temperature layer traps signals to propagate within the duct. Signal can drop out or be refracted up or down to a receiving station. In effect, the signals are trapped in a duct or wave guide. They will travel an almost infinite distance parallel to the surface of the earth, making DX contacts possible for between 100 kms to 5,000 kms and even more. This is a common almost weekly occurrence in areas like the Western Australian coast and extending as far north as Indonesia.

Precipitation Scatter is exactly as you would think. Rain, snow and storm clouds reflect microwave SHF band signals. This is normally most effective in the 10 GHz to 300 GHz range of frequencies.

E-Layer and variants are also known as E's. This is more common to the 10 m and 6 m operator as summer time short skip on 10 m. E-Skip is another common term. In New Zealand and the Oceania region we often find that either side of summer and the equinox periods.

Sporadic-E is a type of ionosphere E-Layer refraction caused by small particles of usually dense ionization.
These sporadic E layers (clouds) appear unpredictably, (sporadically) but they are most common around Oceania during day light hours over spring, autumn and summer. Sporadic E events can last minutes to several hours.
28 MHz, 50 MHz and as high as 144 MHz can be heard during Sporadic E openings.
144 MHz is very rare but I did witness this in 2021 when no tropospheric duct was existing.
The 2 m opening only lasted for a small time but sufficient for a two way FT8 contact with Australia.
My own experience, and that of others in the referenced articles, is to be using only 5 to 10 watts of transmitter power to achieve QSO's. This labels the "Magic Band" title given to the 6 m band.
In December 2020 I worked several VK SSB stations and many more in Oceania using FT8 with only an FT-817 bare foot at 4 watts output. The "Magic Band" and Sporadic-E propagation mode.

Meteor Scatter is due to an ionization layer caused by meteors entering earths atmosphere and burning up. Meteor showers are also forecast so operators have time to prepare ahead of time.
Its a bit like knowing about a solar flare or Coronal Mass Ejection (CME)
The effects are expected to hit the earths ionosphere eventually.

Back Scatter signals are much weaker than normal E-skip signals. They may exhibit multi path flutter (a hollow drain pipe sound) or have a slight echo.

FAI is a newly discovered mode that may exit simultaneously with sporadic-E and then persists after all evidence of sporadic-E has disappeared. FAI signals are generally weak and may easily be confused with back scatter. FAI signals are rough sounding like aurora distortion. SSB is a good as it gets, FM is not good but any communications mode that can handle flutter and warble is a good choice.

Aurora and Auroral E is in use by stations in the southland region of New Zealand.
I know of contacts taking place but have no records listed yet.
Aurora, a rough, raspy, activity is often taken over by Auroral E and quickly transformed into a strong, crystal clear signal. When this happens Auroral E has taken over. This can last minutes to hours.

F and F2-Layer is well known to HF and 10 m operators. This typically is determined by the SFI.

Transequatorial FAI Occurs either side of the equator zones. New Zealand is outside this zone however the mode is included in case ZL stations make a contact while visiting northern pacific islands.

Refraction and Diffraction is most common with Earth-Moon-Earth (EME) and using higher VHF/SHF/SHF Frequencies. Bouncing signal off over head flying commercial aircraft using 10 GHz is well known as a repeatable signal path.
Knife Edge is experienced often in New Zealand with some home stations working a non Line Of Sight (LOS) path Wellington 23 cm repeater. Knife edged over a hill side ridge is a known and repeatable method of QSO between non LOS stations.

Solid Object reflection I have experienced at the Raumati Beach, Kapiti Coast, north of Wellington. Standing on a sand dune with a 10 dB gain antenna and 1 watt hand held I achieved reliable, repeatable QSO's via the Mount Climie 1292 MHz FM repeater. This is a distance of 38 kms from Kapiti Island to Mount Climie and 9 kms from Kapiti Island to Raumati beach. Add to this the reflection loss bouncing off the island (unknown dB's) and the free space path loss of 108 dB (includes the 10 dB antenna gain) it's proof that solid object reflection is a reliable propagation mode.
The conclusion was that a small amount of power will work if the angles are experimented with and the solid object is found to be reflective enough.

Conclusion

Knowing more about propagation paths I hope that operators will be inspired and can attempt more new records on frequencies that have previously used traditional propagation paths and modes.

For example, two stations distanced 300 kms apart, and not LOS, could try a QSO via an aircraft using the 23 cm band. There are a lot of 23 cm 1296 MHz transceivers and transverters in New Zealand.
I'm not sure if 23 cm will work? If not then 10 GHz stations (yes there are a few) could try as this has been successful internationally. Aircraft on regular flight schedules can be tracked on line and a suitable mid way flight path reflection location found.

I encourage operators to have good evidence such as digital logs, audio or visual proof of the QSO. Posted on line this can encourage others to take part in this exciting aspect of amateur radio.

References:

1) QST "The world Above 50 MHz" April 1999.
2) QST "VHF Propagation and the Meteorology" March 1984.
3) QST "Scatter your way to 6m DX" November 1999.
4) CQ "Sporadic E propagation" May 1997.
5) RSGB Radio communication "Tropospheric Scatter Propagation" by W3EP April 1988 .
6) UKSMG Six News Archives "Sporadic E propagation at VHF" September 2005.