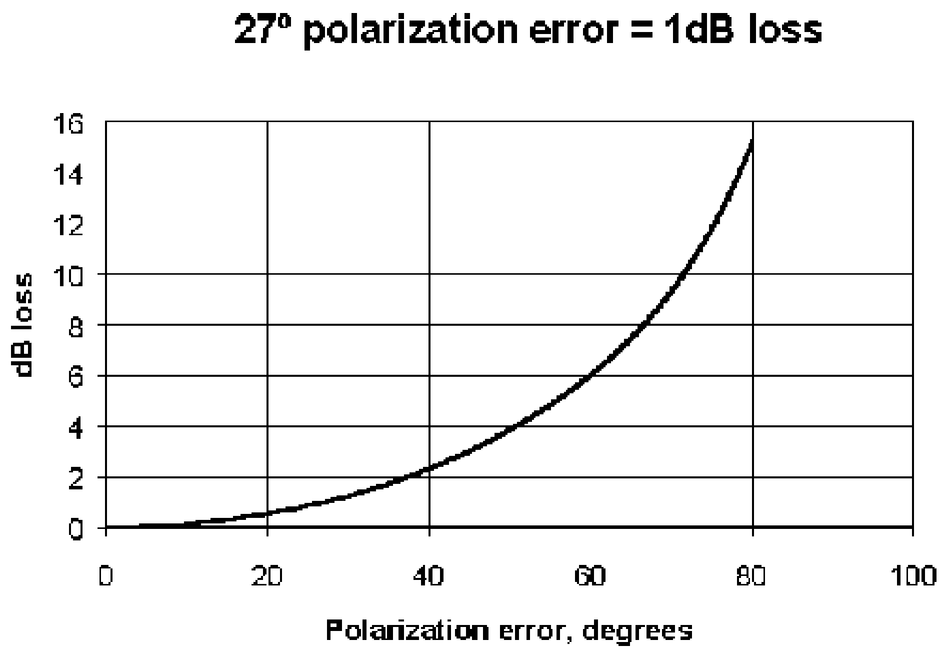
Polarization and "One-way" EME Propagation

Paris 432MHz and Above EME Conference, 1998

Polarization Problems

On 432MHz and below, we all use linear polarization for EME. Yagi stations use the same polarization that we use for other kinds of VHF/UHF DX, which is usually horizontal.

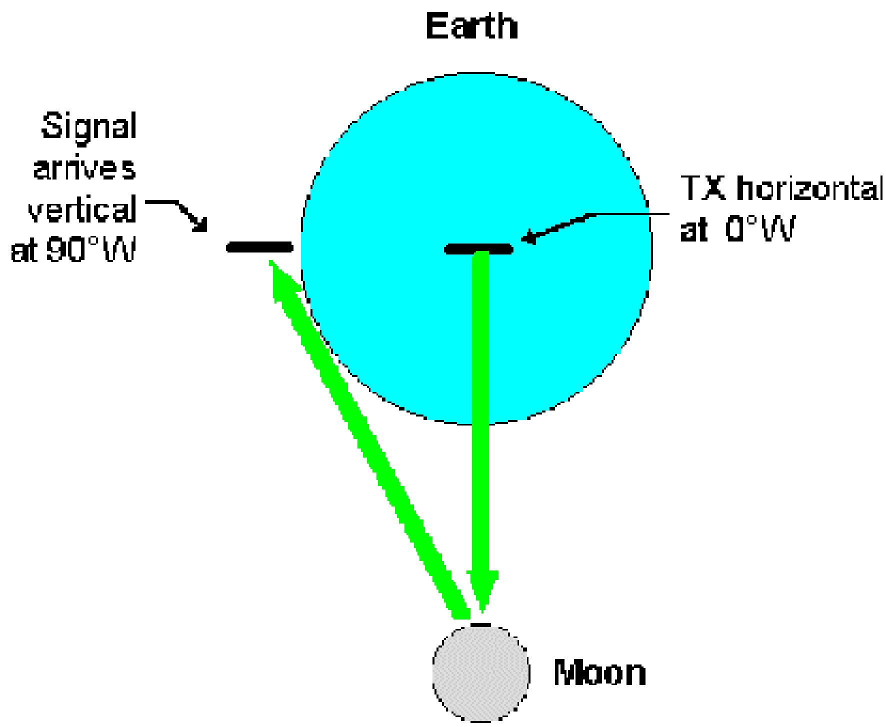
A big problem with VHF/UHF EME is that the transmitted polarization is usually rotated before it reaches the receiving station, so there can be very large losses in signal strength. Remember also that EME signals are always close to the noise, with rapid fading, so even a 1dB loss is noticeable.



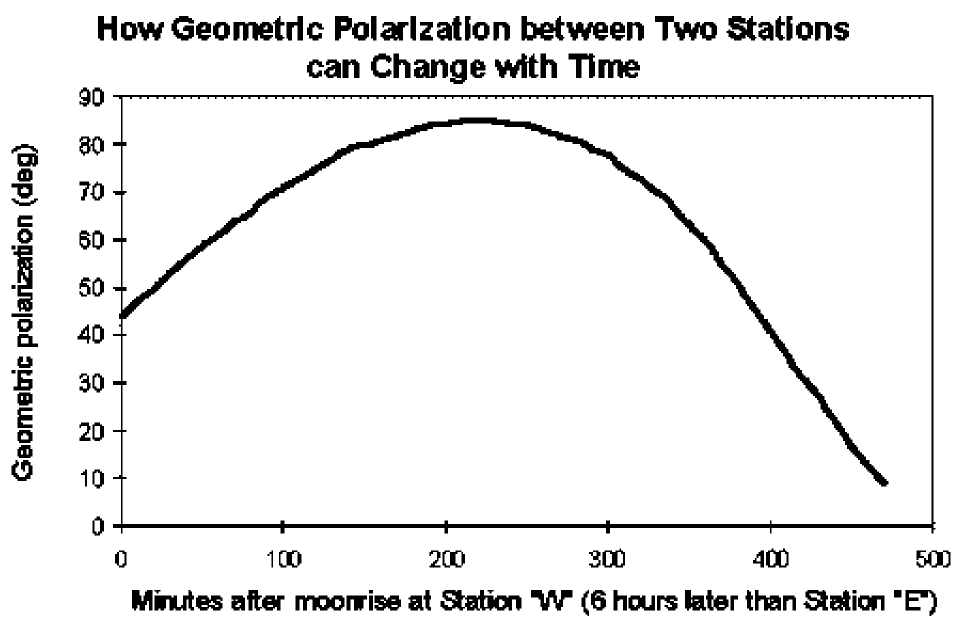
To keep the signal losses below 1dB, the polarization error must be less than about ±(20-30)°. The good news is that the signal loss within the ±20° region is very small.

Geometric Rotation (or Spatial Polarization)

If the transmitting and receiving stations are on two different continents, there will almost always be polarization rotation between them, because of their relative positions on the Earth. This is called geometric rotation (or spatial polarization).



Geometric rotation also depends on the moon's position, so it varies with time on each moon pass. The graph below shows how geometric rotation can typically change, for two stations with a 6-hour local time difference.



See how the angle of geometric rotation changes from +45°, up to almost +90°, and then down again through +45°, ending at almost 0° when the moon is setting at the Easterly station. Something like this happens on every moon pass.

Faraday Rotation

Faraday rotation occurs when a linearly polarized signal passes through the ionosphere. When the electromagnetic wave interacts with the charged particles and the Earth's magnetic field, its plane of polarization is rotated. When the rotated signal has been reflected back from the moon and re-enters the ionosphere, it will be rotated some more in the same direction - Faraday rotation does not cancel out. Faraday rotation can not be predicted in advance: you have to accept whatever it is at the moment!
Faraday rotation is proportional to 1/(frequency)², so that when the ionosphere does change, the polarization angle changes 9 times more rapidly at 144MHz than it does at 432MHz. This can have many unfavourable consequences. At 144MHz in unstable conditions, Faraday rotation can change rapidly enough that you can lose a station before the QSO is complete; but when the ionosphere is stable, the polarization at 432MHz can remain 'stuck' at a bad angle for the whole day.
In disturbed ionospheric conditions, EME signals can also return to earth with their polarization spread over a wide range of angles. In extreme cases the signal strength is the same at all polarization angles, which means an extra signal loss of up to 3dB, or possibly more if there are other significant losses in the ionosphere (this is still under discussion!).

Geometric Rotation + Faraday Rotation = Trouble!

N1BUG has clearly identified that the real problem is not either geometric rotation or Faraday rotation on its own - the problem is the **interaction** of the two effects.
There will always be a combination of geometric rotation and Faraday rotation on an EME path. When you are working a long way East or West, to another continent, the Faraday rotation will probably not be the same at each end of the path, because of the different time of day. As a result, the situation can be very complicated. The tables below shows some simplified cases, for 45° intervals of geometric and Faraday polarization rotations.

Key to table below:

White background	=	can hear – polarizations are aligned
Grey background	=	can hear, but with loss due to polarization mis-alignment
Black background	=	can **not** hear – cross-polarized!

Fixed horizontal polarization		**Geometric Rotation** (station positions + moon position)				
		–90°	–45°	0°	+45°	+90°
Faraday Rotation (iono-sphere)	+90°	**E** hears **W** **W** hears **E**	**E** hears **W** **W** hears **E**		**E** hears **W** **W** hears **E**	**E** hears **W** **W** hears **E**
	+45°	**E** hears **W** **W** hears **E**	**W** hears **E**	**E** hears **W** **W** hears **E**	**W** hears **E**	**E** hears **W** **W** hears **E**
	0°		**E** hears **W** **W** hears **E**	**E** hears **W** **W** hears **E**	**E** hears **W** **W** hears **E**	
	–45°	**E** hears **W** **W** hears **E**	**E** hears **W**	**E** hears **W** **W** hears **E**	**E** hears **W**	**E** hears **W** **W** hears **E**
	–90°	**E** hears **W** **W** hears **E**	**E** hears **W** **W** hears **E**		**E** hears **W** **W** hears **E**	**E** hears **W** **W** hears **E**

What Happens On The Air

The table above identifies **five different cases**:

1. 0° geometric and 0° Faraday give alignment both ways, so the chances of a QSO are good. This means you can hear your own echoes and work your own continent.
2. Any combination of ±90° and ±90° also gives alignment both ways, because the geometric and Faraday rotations cancel out. In this situation, we can sometimes work a far-away continent with good signals both ways, while echoes and signals from our own continent are poor.
3. Any combination of 0° and 90° gives high loss due to cross-polarization - you can't hear echoes, and can't work anybody at all.
4. Any combination that includes only one ±45° rotation gives a 3dB loss, compared with optimum polarization.
5. The combinations of ±45° with another ±45° give **one-way propagation** - one station hears perfectly, while the other station hears **nothing**!
6. The real killer is case 5 (highlighted in red) where geometric and Faraday rotations combine to give one-way propagation. This is most likely to occur when the geometric rotation on a long East-West path is about ±45°, and this situation typically happens two times in every East-West intercontinental moon window.

N1BUG has confirmed this by analysis of EME logs from many stations; he found that two horizontally-polarized stations are very unlikely to work each other at the times when the geometric rotation between them is close to ±45°.

Effects on International Relations

If you have fixed horizontal polarization, one-way propagation is very real - and **very** frustrating!

Sometimes European stations can hear US stations calling CQ, but they never come back to our calls... they just keep on calling CQ because replies from Europe are arriving vertically polarized.

And sometimes it works the opposite way: we in Europe call CQ, but we don't hear the W stations calling us because their signals are arriving vertically polarized over here.

After several hours of one-way propagation, it becomes very easy to imagine that the guys "over there" have deaf receivers... are running too much power... don't want to work us... are not really serious about EME... **none of which is actually true!**