Moon bounce, also called Earth-Moon-Earth (EME), is a form of wireless communication in which the moon is used as a passive satellite. To the uninitiated, this sounds a little like science fiction, but it has been done and continues to be done by experimentally-inclined amateur radio operators.

There are several challenges and difficulties inherent in moon bounce operation. One of the most troublesome for two-way communication is the fact that the moon's distance introduces lag time. The moon is approximately 250,000 miles away from the earth, and radio waves travel at 186,282 miles per second. A signal sent to the moon does not return until 2.7 seconds have elapsed. If two people are engaged in a conversation and one person asks a question, that person cannot expect a reply until at least 5.4 seconds later (the answer must travel to the moon and back, as must the question).

Besides propagation delay, the path loss to and from the moon is considerable. The moon is a relatively poor reflector of electromagnetic rays at any wavelength, including radio waves. Its surface is irregular, and it scatters, rather than focusing, reflected energy. Because of this, sophisticated equipment is necessary to successfully bounce a signal off the moon and hear it return.

Another problem with moon bounce communication is libration fading and Doppler shifting. The moon does not always present exactly the same face; it "wobbles" a few degrees back and forth. This "wobbling," called libration, produces a constant change in every component of any signal reflected from the moon. The returned signal consists of the sum total of countless rays that have bounced off mountains, boulders, crater walls, and other lunar features. The relative phase of these components rapidly fluctuates because of libration, so any signal returning from the moon is "fluttery" and distorted.

Amateur-radio moon bounce generally requires the following:

- A sensitive receiver with a narrowband filter
- A transmitter capable of operating on at least one amateur band above 144 MHz, and capable of producing 1500 watts of continuous radio-frequency output
- An antenna with high directivity and gain, capable of being rotated in both the azimuth and elevation planes
- A location in which the moon can be seen without obstruction for extended periods
- A location in which human made radio noise is minimal
- Neighbors who will tolerate the presence of a large antenna and the proximity of a high-power radio transmitter
- A neighborhood without ordinances or covenants prohibiting large antennas and/or high-power radio transmitters
- Operating skill and patience
- One of the more exotic things that amateur radios do is earth-moon-earth (EME) communication, sometimes called “moon bounce.” As this name implies, radio amateurs actually bounce their signals off the moon. This is the ultimate DX. The approximate maximum separation measured along the surface of the Earth between two stations

communicating by Moon bounce is **12,000 miles, as long as both can "see" the Moon.** (E3A01)

- Because the signal travels such a long way, you need to do everything you can to avoid signal loss. So, for example, scheduling EME contacts **when the Moon is at perigee** will generally result in the least path loss. (E3A03) Perigee is the point at which the Moon is the closest to Earth.
- Because the signals are so weak, it's also important to use equipment with very low noise, so that the signals don't fall below the noise level. That being the case, the type of receiving system that is desirable for EME communications is **equipment with very low noise figures.** (E3A04)
- EME communications can take place on both the 2m band and the 440 MHz band. The frequency range that you would normally tune to find EME signals in the 2 meter band is **144.000 – 144.100 MHz**. (E3A06) The frequency range that you would normally tune to find EME signals in the 70 cm band is **432.000 – 432.100 MHz.** (E3A07)
- As you can imagine, there are not many operators working moon bounce. You don't just get on an call CQ—generally you set up a schedule with another operator to contact one another via moon bounce. At the appointed time, the operators take turns transmitting, while the other listens. **Time synchronous transmissions with each station alternating** describes a method of establishing EME contacts. (E3A05)
- One interesting phenomenon is libration fading. Libration fading of an Earth-Moon-Earth signal is **a fluttery, irregular fading**. (E3A02) This fading is caused by the irregular surface of the Moon, and the peaks can last for up to two seconds on the 2m band. These peaks can actually help operators make contacts when they would otherwise be impossible.
- **MOONBOUNCE VHF PROPAGATION**
- The moon, which had been in orbit for some **5 million years** or more, was used as **a natural passive reflector** by the U.S. Army Signal Corps for the first time on 11 January, 1946 by bouncing radar (Radio Detection And Ranging} signals off the moon during **Project Diana. On 29 November, 1959**, voice transmissions were relayed from Holmdel, New Jersey to Goldstone via this same natural satellite.
  The Moon was also used as a reflector of radio waves by the U.S. Army in the 1950s, when the existing channels between the US mainland and Hawaii failed because of atmospheric disturbances.
  Moonbounce is another way of amateur communication worldwide on VHF , UHF or microwave. Radio amateurs refer to it as E.M.E. i.e. **Earth-Moon-Earth** and this describes exactly what happens; your radio signal leaves the Earth, is reflected back off the moon,and comesback to earth. The reflected signal spreads out, and can be received at any place on earth where the moon is above the horizon. One of the biggest thrills in amateur radio is the first time you let go of the key and actually hear your own voice or signal come back off themoon! In the near future when the moon will be explored by human and establish Lunar Cities there, amateur stations that will be located there will communicate with the amateur radio stations located on earth. Is it not amazing?

Moonbounce, EME propagation

- an overview, summary or tutorial about the basics of Moonbounce or EME radio signal propagation as it is used by radio hams or radio amateurs on the amateur radio bands.

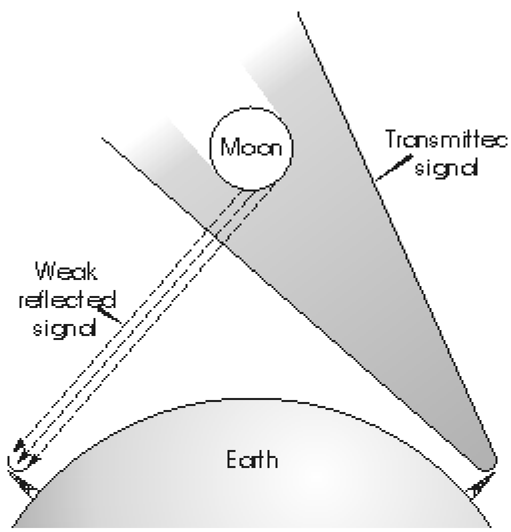
There are many ways for radio amateurs to establish long distance communications at frequencies above those affected by the ionosphere. One is to use satellites, another is to use radio propagation modes such as tropospheric ducting, toposcatter or ever meteor scatter, however it is also possible to use the Moon as a reflector for the radio signals in a mode often referred to as Moonbounce or EME (Earth-Moon-Earth). Although there are difficulties to be overcome, it offers the possibility of making contacts with stations at the other side of the globe on frequencies at VHF and above.

Moonbounce basics

The basis of operation of Moonbounce or EME is the use of the Moon as a passive reflector. In view of the very much greater distances and the fact that the Moon's surface is not an ideal reflector the path losses are colossal, but nevertheless it is still a form of communication that is theoretically possible to use, and one that many radio amateurs regularly use.

To quantify the path losses the distances and reflection efficiency of the Moon are required. The Moon is around 385 000 kilometres distant from the Earth. The surface of the Moon is also reflects only about 6% of the radio signal power that reaches it. Added to the path loss for the signal travelling to and from the Moon, the overall path loss is around 251 dB on 144 MHz and 270 dB on 1296 MHz.

The level of loss also varies because the distance between the Moon and Earth is not constant. There is a "perigee" when the Moon is closest to Earth and an "apogee" when the Moon is at it furthest point from the Earth each month. This distance variation results in a difference in path loss of around 2 dB between the apogee and perigee positions. For small stations where making contacts using Moonbounce may be marginal, the choice of time in the month can make a difference.



Concept of Moonbounce EME propagation

With radio signals being very low, it is found that galactic noise becomes a significant factor. This noise emanates from a variety of sources in the galaxy - planets, stars, etc. emit noise throughout the radio spectrum, and EME systems are very sensitive and will be able to hear this noise. The level of noise is not constant across the sky and this means that some times the sky around the Moon can be very noisy and at other times it can be much quieter. It is found that sky noise is normally worst when the Moon is crossing the galactic plane (i.e. the Moon appears in the Milky Way) and this occurs twice each month.

Fortunately software used for EME Moonbounce indicates this and this helps choose the optimum times for any activity.

Equipment considerations for EME Moonbounce

To overcome the losses and enable radio communications to be established using Moonbounce, very high radio transmitter powers, directive antennas and very sensitive receivers are required. With the distance of the Moon and its diameter being 3475 kilometres it subtends an angle of only 0.52 degree to observers on the Earth. In order to illuminate the Moon with little wasted power either side, enormously directive antennas are required. Also these antennas must be completely steerable to be able to track the steadily changing position of the Moon.

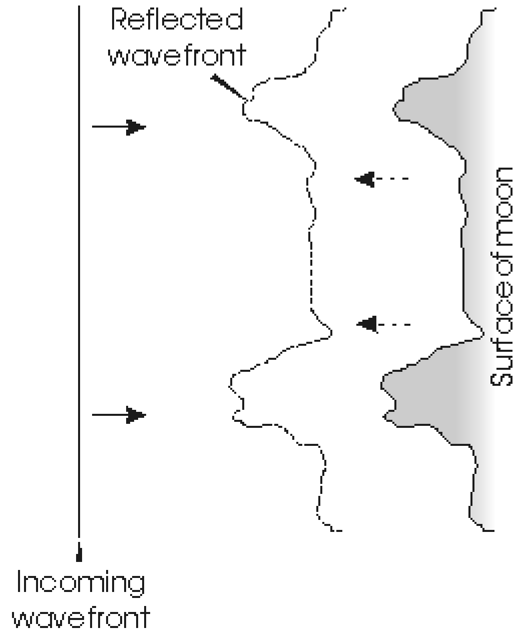
Frequencies used for Moonbounce are generally in the VHF or UHF portion of the spectrum. This allows antennas with sufficiently high gains to be used to overcome the path losses. Although frequencies as low as 50 MHz have been used, it is more normal for the 144 MHz, 432 MHz or 1296 MHz amateur radio bands to be employed.

Moonbounce propagation effects

In addition to the path losses themselves the EME, Moonbounce signals are subject to other signal propagation effects:

- ***Faraday rotation:*** At frequencies of 1296 MHz and above it is not a problem, but on 432 MHz it is believed that rotations up to 360 degrees are common, and below this the signal may rotate through several complete revolutions. This may result in stations only being able to communicate in one direction at times.

- ***Libration fading:*** This effect occurs on EME Moonbounce signals because the surface of the Moon is not flat and the reflected signal consists of a variety of wave-fronts each with differing phases because the distance travelled by each one is slightly different due to the rough Moon surface. The received reflected signal is therefore a sum of all the wave-fronts. As the Earth and the Moon are moving relative to each other the sum of these wave-fronts is always changing and this results in a signal onto which is superimposed a rapid flutter as well as deep fading (sometimes up to 20 dB) and some peaks. These peaks can often be very helpful to stations with less power or smaller antennas.



The reflections seen from the Moon

After reflection by the Moon, wavefronts have a variety of phases which sum to give the overall signal. As these change with the relative movements of the earth and the Moon this results in libration fading.

- ***Doppler shift:*** The relative movement of the Earth and the Moon can result in some degree of Doppler shift being add to the signals. This will vary according to the relative movements of the two bodies, and also to the frequency in use. As an example of how Doppler shift affects a Moonbounce / EME signal it is found that at "Moonrise", a 2 Metre signal may be shifted up in frequency by as much as 350 Hz. It is then found that this figure reduces, reaching zero when the Moon is passing the particular longitude in which you are located (due south or due north azimuth heading) After this, the Doppler shift starts to move in a negative direction, reaching an offset of around 350 Hz LF by "Moonset." As signal levels are low using EME Moonbounce, very narrow bandwidths are often used and as a result Doppler shifts can be of importance.

- ***Signal polarisation changes:*** Another problem that can occur with Moonbounce is that as stations are located at different positions around the globe, a horizontally polarised signal in one area of the globe will be at right angles to a horizontally polarised signal a quarter of the way round the globe. This spatial polarisation problem adds to the difficulties caused by Faraday rotation.

Operating using EME Moonbounce

In view of the specialized requirements for Moonbounce, EME, some of the operating techniques used have been adapted to enable the best level of communication to be achieved. As EME is a weak signal mode, most of the contacts have traditionally used Morse, although some stations with high powers and very high gain antennas are able to use SSB on occasions.

When using Morse speeds are generally kept to speeds between about 12 and 20 words a minute. The reason for this is that if the speeds are too high then copy becomes difficult in the presence of noise whereas if the speeds are too slow then the characters become affected by the libration fading which again makes copy difficult. Additionally the weighting on the individual dots and dashes is often increased slightly to aid copy.

A good first check of a station can be gained by listening for echoes of one's own signal. If these can be heard then there is a good chance of others hearing. However even if the echoes cannot be heard, it is possible that others with higher gain antennas may hear.

Although many stations call CQ, this is only viable for stations using high powers and high gain antennas. For stations where signal strength may be marginal arranged contacts produce a far better possibility of a contact. These arranged contacts use accurately timed transmit and receive periods to enable the participating stations to have the best chance of communicating.

Various sections of the band are used for EME. A high proportion of the Moonbounce operation takes place on 2 metres where random operation is typically between 144.000 to 144.045 MHz and arranged contacts may take place on frequencies up to 144.170 MHz. For arranged contacts it is necessary to be able to accurately set the frequency to enable the other station to have a good chance of hearing.

EME Moonbounce summary

The use of E-M-E propagation or Moonbounce is a challenge to any radio amateur wanting to use this mode of radio propagation, but it can yield some excellent results. Those with the right equipment are able to make contacts with stations in many different areas of the globe when the Moon is in the right position relative to the Earth. In this way it is a particularly interesting form of propagation to use.