Moonbounce – Receiving EME (Earth-Moon-Earth) Transmissions

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My capstone project is on the topic of Earth-Moon-Earth transmissions. What this means is that signals transmit from Earth, go up through the atmosphere and contact the moon, reflect off the moon, and travel back towards Earth. HAM radio enthusiasts have been doing this for many years, but the process involved varies from case to case. In most cases a signal is sent by the individual attempting the moonbounce operation and is then received by the same person. In the case of my experiment, I decided to forego the initial transmission and instead let a radio broadcast station do it for me. Not only would this save money, it would also produce a larger signal than what I would be able to produce on my own.

The idea behind this is to use the Moon's reflective properties when it is in the correct position above the horizon for reflection. The station I picked to receive transmission from was KPFK 90.7 out of Malibu, CA. This station is 43º away from Newport News, where I would be attempting to receive the transmission. What this means is that I would need to conduct my experiment with the moon at 43º above the horizon. This would put the moon in direct tangent line to the radio broadcast tower's location, letting the Moon do the rest of the work by reflecting the signal to me.

Results in this experiment would depend on multiple variables. These variables included signal degradation, Moon position, Moon reflectivity, antenna type, antenna size, receiver sensitivity, and transmission/reflection patterns. It seemed that many of these variables tied into the most predominant of them all, signal degradation, so that became the first step in the process.

In calculating signal degradation, I used several constants. The first of these constants was 384,400 km, the Moon's average distance from Earth. I would use this constant in combination with the area of the broadcast signal, which goes out in a torus pattern, to find the degradation on the way to the Moon. The area of a torus is defined as 4*pi^2*R*r, R being the distance from the center point to the center of the torus ring, and r being the distance from the center of the ring to the outside. Since the particular torus pattern radio signals broadcast is known as a horn torus, R=r, so it just became r^2. Using this formula, I found that the area of the radio broadcast signal at the moon's distance would be 1,458,363,444,518.8 km^2. After calculating the area, I needed the percentage of this area that the Moon would actually come in contact with. To do this I calculated the average cross sectional area of the Moon using its average radius, 1737.1 km, and the formula for area of a circle, pi*r^2, to get 9,479,799.4 km^2. Dividing this number by the area of the broadcast torus I calculated a signal degradation of 6.5*10^-6, since only this area would actually be used as a reflection surface. After that, the Moon's reflectivity comes into play. On average the Moon is 7% reflective, so this number has to be multiplied by 0.07 to end up with 4.55*10^-7. Once the signal bounces off the Moon, it broadcasts in all directions in a hemispherical pattern. Again using the distance between the Earth and moon along with the formula for half the area of a sphere, 2*pi*r^2, we get a value of 232,105,947,071.2 km^2. Using the average cross sectional area of the Earth, 127,516,010.3 km^2, calculated from its 6371 km radius, we can then calculate the signal degradation back to Earth. The signal degradation for the whole process ends up being around 1.8*10^-24. This means for each watt of signal sent out, you will receive 1.8*10^-24 watts of return signal.

Since this signal degradation was so extreme, a large antenna had to be used. The antenna type chosen was “Yagi-Uda.” This type of antenna, commonly referred to as a yagi, fit the requirements of the experiment by being very sensitive and being highly directional.

What this means is that if we point the antenna at the Moon, the yagi antenna should theoretically only pick up signals from the Moon, provided it is high enough for the yagi's 30º cone of reception to not include transmissions from the horizon. The antenna I ended up using was six feet long. Since the wavelength of the radio signal boradcasted was between two and three meters, an antenna this large was necessary to pick up the signals.

In order to save money and hopefully not sacrifice much quality, I used an older model radio receiver. This receiver had older functions and most of the controls were manual, but it still hooked up to the antenna just the same. This saved around $200-300. The next step in the experiment would be to test it.

For trial one, Dr. Gore and I arrived on campus at 2:30AM on April 12th with the materials needed to assemble the antenna/receiver setup. After arriving at the location that we had previously decided upon, we ran power and speaker wire to the receiver. We then attached the antenna via coaxial cable. The antenna had to be mounted on a non-conductive mast and needed to be pointed at an upward angle. This was accomplished by two holes at roughly a 43º angle through one end of an eight foot two by four. We then tied this assembly to a tripod so that the antenna would not fall when we were not holding it.

Upon tuning to 90.7 FM, a strong incoming signal was received while the antenna was pointed towards the moon. This seemed too strong to be moonbounce, however we checked it reguardless. Our findings were that this station originated somewhere in the Hampton Roads area and was in fact not a moonbounce like we initially suspected. Since the local station was masking any signal that we might get from moonbounce, we decided to look for a station with a relatively high amount of static that only was audible while pointed at the Moon. Over the course of the next few hours we encountered three false positives which were thrown out once each station identified itself as within local broadcast range. Apart from these false positives, we did encounter one station that seemed to be too far away for a normal broadcast signal. This station originated out of North Carolina and seemed to be stronger when the antenna was pointed above the horizon. We theorized that this was a radio signal bounce off of the Ionosphere and concluded that we would need to compare results after a second trial.

The second trial went much like the first, there were a few false positives again, however when I tuned to the station in North Carolina, I did not receive any broadcast even though the antenna was pointed in the same direction. This confirmed our initial theory that the signal reception was on account of Ionosphere bounce. Since the Ionosphere moves up and down between night and day because of the level of solar radiation from the sun, it was expected that the same Ionosphere reflection would not occur on the second test. The reason for this was that the first test occurred before dawn whereas the second test occurred well after. Even though the Moon was in the same general location, the Ionosphere was not.

While our results did not show any type of moonbounce, none of the data that we collected is useless. The directionality of the yagi antenna was confirmed during our tests and, while it can pick up signals from other directions if they are very strong, it does have the ability to pick up a weak Ionosphere bounce when aimed in the right direction. We also realized that a signal transmitted towards the Moon may have been a better idea for several reasons. For one, it could be tuned to a frequency where there is no local interference. Additionally, it could be aimed directly at the Moon so that it would not need as much power to reflect a higher ratio of the original signal off the Moon. Much of our signal decay was due to the large area of the original boradcast. If the original signal could be pinpointed, it could cut down the decay ratio by as much as 10^6. This would increase the likelyhood of the receiver being able to pick up the initial transmission. Additional steps to increase the probability of the success of this project could include using larger yagi's or several linked together. Also, while we initially decided against a dish style antenna because of size and transport issues, it may be a possibility for future tests provided it can be assembled in the desired test location. I would have liked to have more time to work on this, however I was limited to one semester. I believe that the time and effort put into this project was not wasted and hopefully can be added to in the future.