144 MHZ SINGLE YAGI EME

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The contacts between amateur radio stations via moon bounce propagation had always required very sophisticated antenna system with high gain, only available with configurations of several coupled Yagi antenna. In fact, the Earth-Moon-Earth path is over 700,000 kilometres, with a great path loss related with the poor radio reflection capacity of the lunar surface (at 144 MHz only about 7% of the energy impacts is reflected back from the moon) and the variability of Propagation conditions is another further complication. Digital transmission designed and developed by Joe Taylor, K1JT, Nobel Prize for Physics in 1993, has revolutionized the world of EME communications and opened up the way to normal stations. The software of Joe Taylor has opened a new era in moon bounce communications. Using the WSJT (JT65B mode) software is possible to make some EME qso with a single Yagi antenna and 100 watts of power output. The best chances occurs when the lunar orbit is at perigee (nearest point to the earth) and when the sky noise temperature is low.

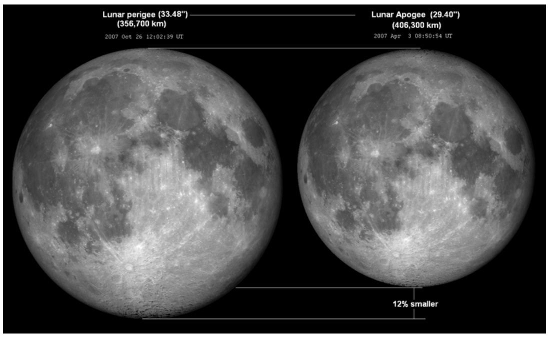

Fig.1 Moon makes a slightly elliptical orbit in 28 days, the nearest point to earth is the perigee (356,700 km) and the farthest point from the earth is the apogee (406,700 km). The path losses are -251.5 dB at perigee and -253.5 dB at the apogee.Signal delay time is about 2.4 sec and 2.7 respectively. WSJT, if both stations are properly synchronized is able to detect with good accuracy this signal delay.The Figure above shows how the moon as appears from an Earth observer when it is at perigee and apogee, the difference size is about 12% and this means a difference of about 2 dB of path losses (at 144 MHz).

Noise

One of the most important things in the development of the EME station is the accuracy of the receiving section in order to reduce the noise level. Even some few decibels can make a great difference between hear or not hear the radio echo from the moon. The best thing is to use a low noise antennas configuration, with good quality low noise amplifier (LNA). Galactic noise is always present, although it varies periodically with the movement of the moon along the elliptical (see Figure 2). The urban noise is very difficult to manage. Working EME propagation with a low noise level can makes the difference especially for qrp station like me. This is possible by taking some action and use very low loss cable, the antenna shape with narrow bandwidth, and a very sensitive receiver. In this context, WSJT software makes up a big help, you can extract and decode signals from the noise up to -26 dB and even up to -29 dB using a special software function (average deep search)

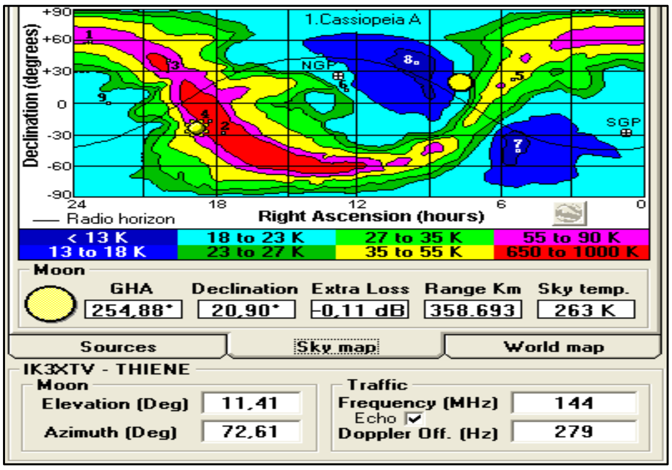

Fig.2 Map of the sky with different temperatures of noise. The diagram indicates our galaxy, the Milky Way. Sinusoidal line represent the plane of elliptical. The sun takes his path along the elliptical in one year. The moon moves roughly along the elliptical line (+ / - 5°) each month. When the m oon passes in direction of the sun the EME activity is very difficult for the high cosmic background noise (red zone). This happens periodically during the new moon phase, when we have a very high moon degradation level.

Ground gain

Working on the rising and setting of the moon, (then 1 to 18/20 degrees of elevation) You can use the ground effect with an additional gain can theoretically reach 6 dB, this means a single yagi get roughly the performance of an array of 4 Yagi. The gain ground depends on the land all around the antenna, for those station located in the urban area, like me, this value is definitely lower. If the EME station is located in the open countryside or better close to the sea, the situation could be improved considerably. Without antenna elevation, you can capture the moon from 0 degrees to about 18/20 degrees , then working on the moonrise and moonset you will have available about 3 hours a day.

Additional factors that influence EME propagation

The gain ground alone is not sufficient to support the EME propagation for QRP station. There must be some additional factors are not currently known that could increase and amplifies the echo strength l. The eme signal must traverse two times the ionosphere , with portions of the ionosphere often very different. Because of this Transit the radio waves undergoes Faraday rotation, which introduces a mismatch that often does not allow the reception. We do not know, for example, if this ionospheric path can introduce some favourable actions. Moreover we know that not all the lunar surface has the same type of reflection property. Rather seems that the areas that most contribute to the reflection are localized at the center of the visible disk, and we do not know if there are some other factors contributing to the signal scatter. On the other side, on the earth, there are several factors that can worsen and why not, in certain times to increase the signal: there is not only the ionosphere, but also Earth's magnetic field and even the earth's magnetosphere as even approaches with the tail the lunar orbit. I am of the opinion that the magnetosphere can not play a secondary role in the dynamics of Earth-Moon-Earth propagation. In further support of these assumptions, I noted that even on EME propagation , as there is in ionospheric HF propagation, I have found some preferential pathways. For example, on my side I have better condition about Europe-Europe, especially EU-EU to east direction. Consider the angle formed between Earth-Moon-Earth with two stations located in different continents, the radius of incidence reflection on the lunar surface can differ up to 2 degrees. This complication has

an impact in both sides (inside the ionosphere) and over the lunar surface because it can change the angle of signal reflection in order to affect the quality of the moon echo. Something of similar could be happens with the libration (please see notes). Some previous research discover that radiowaves are reflected back to the Earth principally from a small region at the center of the visible disk, even small movements of
this area due to libration and especially at a different angle of incidence of the beam wave can have a significant impact in the echo strength. The best hours to operate EME are those night, because the noise is reduced and ionospheric absorption is very low . At 144 MHz this value is about 0.5 dB, than during the night this value is about 10 times lower.

WSJT JT65B EME communications

JT65, developed and released in late 2003, is intended for extremely weak but slowly-varying signals, such as those found on troposcatter or Earth-Moon-Earth. It can decode signals many decibels below the noise floor, and can often allow amateurs to successfully exchange contact information without signals being audible to the human ear. Like the other modes, multiple-frequency shift keying is employed; unlike the other modes, messages are transmitted as atomic units after being compressed and then encoded with a process known as forward error correction (or "FEC"). The FEC adds redundancy to the data, such that all of a message may be successfully recovered even if some bits are not received by the receiver. (The particular code used for JT65 is Reed-Solomon.) Because of this FEC process, messages are either decoded correctly or not decoded at all, with very high probability. After messages are encoded, they are transmitted using MFSK with 65 tones. The transmission period is 50 seconds , after software passes on reception and so on. The received signal is analyzed
according to the Fourier transform that it is a mathematical procedure specific for data analysis. JT65 for a correct decoding requires a good time PC synchronization for example with a NTP server.Wsjt provides various modes of transmission, for EME communications the mode used is JT65B.

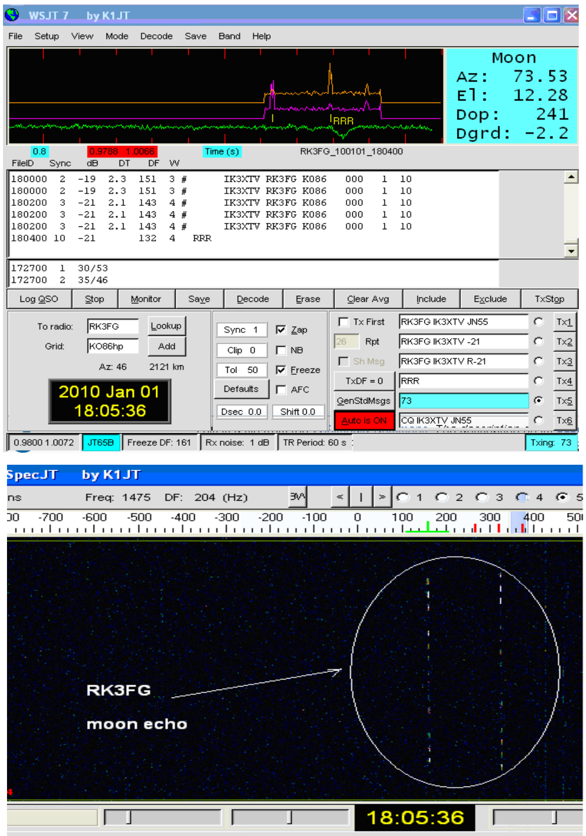

Fig.3 Screen shot of the EME qso 01.01.2010 with RK3FG (4x15 elements) with good conditions, Moon at perigee and low sky noise temperature.

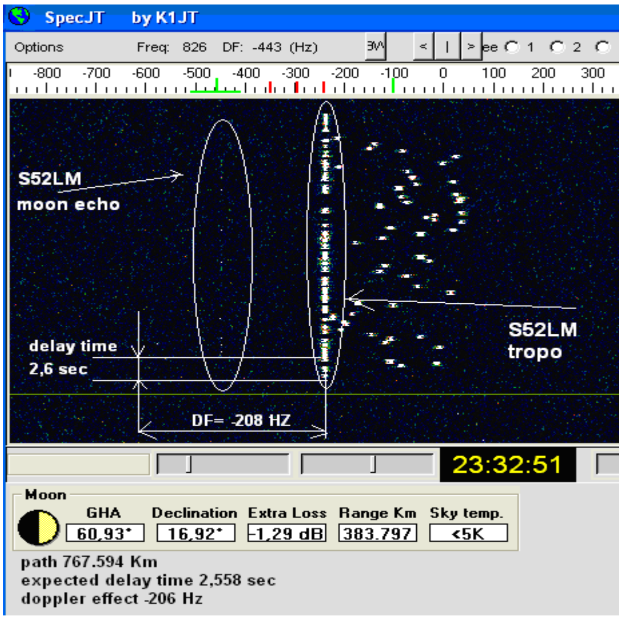

Fig.4 Experiment of EME and tropo reception with S52LM (4x17 1.5 kW) just to highlight the differences and characteristics of the moon echo compared with a tropo signal.The WSJT software has detected a delay time of 2.6 seconds. (The Calculation of the DT for a range of 383,797 kilometers away, is DT = d / c where d is the earth-moon-earth path range and c the speed of light DT = 767,594 / 299 792.458 = 2.56 sec) with a frequency shift of -208 Hz. The tropo signal was detected at -7 dB and the moon echo at -26 dB.I did this test at the moonset when the moon signals are afflicted by a negative doppler effect while at the moonrise, the doppler is positive.

NOTES:

Lunar libration (from Wikipedia)

In science (particularly astronomy), libration (from the Latin verb librare "to balance, to sway", cf. libra "scales") is a certain type of motion where an object has approximately a fixed orientation, but instead of staying exactly fixed in that orientation, rotates slightly back and forth in an oscillatory manner. (Everyday examples of this motion include the motion of an empty rocking chair, or the swaying of a balance scale.)The term is most commonly applied to astronomy, describing the motion of orbital bodies, particularly the moon.[1] It is also used in physics and chemistry to describe molecular motions in solids and liquids. The moon generally has one side face the earth, due to tidal locking: The dark side of the moon was never seen by humans until the advent of space exploration in the 1950s. However, this simple picture is only approximately true: Over time, more than half (about 59%[2]) of the moon's surface can be seen from the Earth's surface, even though the front of the Moon is tidally locked to always face towards the Earth.As orbital processes are repetitive, libration is manifested as a slow rocking back and forth of the face of the orbital body as viewed from the parent body, much like the rocking of a pair of scales about the point of balance, permitting an observer to see slightly differing faces of the surface at different times.
There are three types of lunar libration: Libration in longitude is a consequence of the Moon's orbit around Earth being somewhat eccentric, so that the Moon's rotation sometimes leads and sometimes lags its orbital position. Libration in latitude is a consequence of the Moon's axis of rotation being slightly inclined to the normal to the plane of its orbit around Earth. Its origin is analogous to the way in which the seasons arise from Earth's revolution about the Sun. Also significant is the fact that the Moon's orbit is inclined to the plane of the ecliptic by a little more than 5°. As it is the Sun which illuminates the Moon - and both the Sun and the Earth are always located in the plane of the ecliptic - the Moon is sometimes illuminated from above and sometimes from below, allowing us to see some of the lunar surface beyond the poles. Diurnal libration is a small daily oscillation due to the Earth's rotation, which carries an observer first to one side and then to the other side of the straight line joining Earth's center to the Moon's center, allowing the observer to look first around one side of the

Moon and then around the other. This is because the observer is on the surface of the Earth, not at its centre.

Software

WSJT freeware download
http://www.physics.princeton.edu/pulsar/K1JT/

Software for moon tracking
EME System di F1EHN
http://www.f1ehn.org/

chatrooms / loggers
http://www.chris.org/cgi-bin/jt65emeA

EME test configuration
-Antenna YAGI 13 elementts (3WL) 15,3 dBd
-Solid state PA (n. 2 MRF245 push-pull) max output power 150W
-LNA gasfet transistor NE41137 (23 dB NF<1Db)
-Rtx Kenwood TS711E
-Digital signal processing " SP-1 Contel" (used as noise reduction)

Bibliografy
Wikipedia
DF5AI Dr. Volker Grassman
Eme system di F1EHN, software tracking luna
WSJT di Joe Taylor, K1JT
144 Mhz eme basicc weak signal vhf by Tim Marek, K7XC
Space communications (physics.princeton university)