MOON – EARTH – MOON

2nd Part

EA4CYQ
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I feel that I have left you a little discouraged in the previous article, because I have only shown the problems that we must overcome to get an EME QSO. I try to relate them:

- Losses in the way, remember at 144 MHz are 252.1 dB.
- Doppler Effect, which moves the frequency of the signal that has been emitted.
- Libration, which distorts the signal after being bounced on the rough surface of the Moon, moreover Moon is not a wall, it is spherical.
- Spatial rotation added to the Faraday Effect, which randomly changes the polarization of the signal.
- Space Noise and Ground Noise, under which the signals we receive are buried.

In this second article, I will try to develop the solutions that radio amateurs have adopted to overcome this immense challenge.

THE LOSSES OF THE WAY

It is clear that this can only be overcome with gain in the antennas, minimizing losses to the receiver and with watts of the amplifier. But what is the limit?

When EME started, the decoding limit of the received signals was in the ability to discern the signal between the noise by the human ear. The most effective method was the CW, later filters were applied in the audio chain to get the dots and dashes, but there was the border. In these conditions the minimum antennas and power for a station to hear its own echo, under acceptable conditions are:

Band (MHz)	Antenna	Gain (dBi)	Wide Main Lobe (º)	Power (W)
50	4x12m	19.7	18.8	1200
144	4x6m	21.0	15.4	500
432	4x6m	25.0	10.5	250
1296	3m	29.5	5.5	160
2304	3m	34.5	3.1	60
5760	2m	39.2	1.8	60
10368	2m	44.3	1.0	25

Including 1296 MHz onwards, the antenna refers to the diameter of a parabolic dish.

This table published in the Hanbook will serve as the basis for many interpretations, which I will try to clarify.

Nowadays apart from the CW, we use a PC-based communication protocol called WSJT, designed by our fellow Nobel Laureate in Physics Joe Taylor K1JT. The connection of the transceiver to the PC is via a sound card, just like PSK31, OPERA, etc.

WSJT has revolutionized the world of EME making it accessible to really small installations, as it allows to decode signals 6-7 dB below the audible limit by the human ear. Someone will tell you that it even reaches 10 dB or more, but the conditions have to be exceptional and I try to report a reality.

Translated into real life, 144 MHz and CW require 4x6 m/500 W, to be able to listen between two equal stations, or what is the same, to hear your own echo. But with WSJT, a 4x6 m/500 W station will be able to make contacts with 6 dB smaller stations, that is, with stations 4x6 m /125 W.

Qualify an usual misunderstood, 4x6 m is equivalent to 2x12 m in gain terms, in the end what counts is the length of the total boom, whether we divide it into 2 antennas or 4. Theoretically, 2x12 m will work better than 4x6 m, because having less phasing losses .

Another qualification, someone could tell me, since 6 dB is equivalent to reduce 4x6 m to 1x6 m (remember that every 3 dB is equivalent to doubling / dividing power or boom length), transmitting both with the same power, right!. Theoretically yes, but not really, I explain: *An antenna of 4x6 m has a radiation angle in the main lobe much smaller than an antenna of 1x6 m, and as the moon represents only 0.5º, it turns out that the antennas of 4x6 m/125 W (**16º main lobe**) have a lot more RF on the Moon than an antenna of 1x6 m / 500 W (**main lobe 35º**), although theoretically we talk about the same dB.*

In my experience, I have 4x5 m/750 W, work with certain comfort stations similar to mine and above. In good conditions, I have worked many stations of 2x5 m/1 kW, which is usually used in expeditions (typical 2x9 Elements of M2), but I have also worked many stations of 1x10 m/1 kW (typical 10M2). Even in very extreme conditions (that leave the reality), I worked some station of 12 elements, and I even decoded stations of 8 elements taking advantage of "GG", but these are exceptions.

In order to have a little more gain, some stations take advantage of the "Ground Gain" or "GG", that is, in certain elevation angles close to the horizontal plane, an additional gain takes place when taking advantage of the reflection of the ground. This depends on the surrounding terrain and the location of our antennas. ON4KHG has made a study and very relevant information of its achievements, when obtaining with 12 elements and 300 W, 297 different stations.

SPATIAL NOISE

The main radiation lobe of our typical 4x6m antenna is over 16 °, this is defined as the aperture in degrees where the gain of the antenna drops 3 dB with respect to the maximum gain, which occurs at 0 °.

The Moon, seen from Earth, represents only 0.5º. This means that we will receive the bounced signals on the Moon and all the noise from the space behind. We can only fight by installing antennas with less angle of radiation of the main lobe or by means of filters. EME is usually chosen to work on days of least degradation.

TERRESTRIAL NOISE

The earth noise generated by the temperature of everything around us cannot be avoided, we will have to wait for colder days, the night or some filter can help us.

But the noise generated by human activity is a problem. When after traveling the signal along 2.5 sg at the speed of light, we cannot see it on our screen because our neighbor's LED bulb prevents us, by the small switched power supply without filters that it has installed, What a disaster!

If we see an increase of the terrestrial noise, we have to chase and search all around until we find the problem and try to negotiate. As you see EME in downtown is practically impossible, even if you are a little away, when you aim the antennas towards the cities you see the increase in noise.

The second ideal is not to receive it. I see you, some of you are starting to laugh, to see where I'm going to end. What a station receives is the antenna, if there is something where the radio amateurs have investigated is precisely in this field, with the only objective of receiving what is intended and discarding the rest.

So far I have only spoken of antennas by their length and gain, we can express it in meters or in wavelengths (wl, nλ). What we are clear is that within a number of wavelengths cannot perform miracles, so why are there so many different antennas?. The answer is that an antenna does not have a unique parameter, it has some mechanics (which at the moment are not considered) and other electrical:

- <u>Electrical Parameters</u>:
1.- Gain
2.- Relationship between Gain Front and Back
3.- Angle of radiation of the main lobe with respect to the ground (horizontal plane)

4.- Radiation angle of the horizontal main lobe
5.- Radiation angle of the vertical main lobe
6.- SWR
7.- Bandwidth
8.- Impedance
9.- Power that they support
10.- Temperature of the antenna
11.- Temperature due to internal resistance
11.- Electrical length of the boom

Only to develop it would give for several articles, very interesting, but we will concentrate on those parameters that affect the noise.

Gain (G)
For a given design and frequency, the maximum gain is defined as the main lobe gain. In relation to the gain is the angle that forms the lobe between two points in which its gain falls 3 dB. This gives us an idea of the sharpness of the lobe, which will allow us to concentrate more energy towards where we want to hear or bounce.

Temperature (T)
The temperature is a data that gives us the modeling software, and is directly related to the resistance of the elements that make up the antenna and to the elimination of lateral and back lobes, concentrating the energy in the main lobe.

If you tie cables, the worst noise comes from the terrestrial activity. This means that if I have several lateral lobes, both in azimuth and in elevation, when I aim my antenna towards the Moon I will be receiving through these lobes the terrestrial noise (yes, that of the surveillance camera on the opposite sidewalk).

So why are not the antennas designed with minimum temperature and maximum gain?. For the simple reason that all the electrical parameters, absolutely all, are related and if we stand out one, we sacrifice others. In this sense there are many radio amateurs who have dedicated many years with hard effort to improve designs, in the net you can find G0KSC, K1FO, YU7EF, YU7XL, DK7ZB, EA7JX, etc.

Following the analysis of so many parameters, a parameter was defined in relation to the noise, which is currently marking the differences between the designs, G/T. It is defined as the reception capacity of an antenna, at a more positive G/T figure, the better the antenna will be in reception, in relation to the surrounding noise. Do not scare, It is the only equation I'm going to set, and it's the one that defines G/T:

$$G/T = (G_a + 2.15) - (10 * \log T_a)$$

- G_a = Maximum gain of the main lobe in dBd
- T_a = Total antenna temperature in degrees Kelvin, takes into account all the lobes and the

internal resistance of the antenna

At the moment it is assumed by the whole community of amateur radio that the tables of Lionel VE7BQH, which you can find in any internet search engine, is the best comparative of antennas of 50/144/432 MHz, both experimental and commercial. I can only say that to get a low temperature you have to sacrifice something the gain of the main lobe, as well as increase its angle, but in return we will have "filtered" the surrounding terrestrial noise.

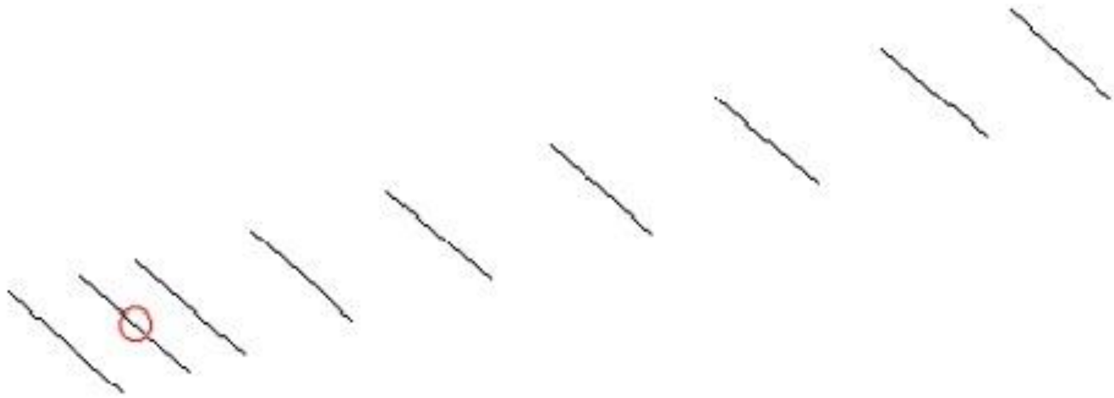
Nowadays there are antenna modeling software that take into account all these parameters, and we can priority those that interest us:

- The bandwidth.
- The front-back relationship, to eliminate the noise and the stations behind.
- A low radiation angle to be able to make DX bouncing in the ionosphere.
- Etc.

								< H Plane >							KF2YN
TYPE OF ANTENNA	L λ	GAIN (dBd)	E (M)	H (M)	Ga (dBd)	Tlos (K)	Ta (K)	F/R (dB)	1st SL (dB)	2nd SL (dB)	Z (ohms)	VSWR Bandwidth	G/T (dB)	Feed System	Convergence Correction req.
+KF2YN Boxkite4	0,43	11,10	3,50	2,00	16,80	3,9	225,7	23,4	22,0	none	50,4	1.12:1	-4,59	Dipole	Yes
+Eantenna 144LFA4	0,59	7,91	2,68	1,74	13,99	2,0	250,7	17,7	none	none	49,4	1.21:1	-7,85	LFA Loop	Yes
+Eantenna 144LFA5	0,87	8,94	2,44	1,99	14,94	3,2	237,1	18,9	18,3	none	53,4	1.09:1	-6,66	LFA Loop	Yes
G4CQM 6	1,00	9,46	2,60	2,17	15,44	7,9	249,7	18,9	17,1	none	56,7	1.83:1	-6,38	Dipole	No
+KF2YN Boxkite 6	1,04	12,47	3,90	3,00	18,25	4,6	263,1	26,5	22,9	24,8	49,9	1.20:1	-3,80	Dipole	Yes
Vine 6 FD	1,10	9,69	2,64	2,21	15,67	8,2	238,4	24,1	18,4	none	48,3	1.18:1	-5,95	Folded Dipole	Yes
G0KSC 6 LFA	1,13	9,69	2,60	2,19	15,64	4,0	236,9	24,4	19,8	none	49,5	1.03:1	-5,96	LFA Loop	Yes
DD0VF 6	1,16	9,73	2,63	2,22	15,71	5,5	240,1	23,7	16,4	none	27,2	1.07:1	-5,94	Dipole	No
*DD0VF 6	1,16	9,73	2,30	2,30	15,58	5,5	245,1	23,7	16,4	none	27,2	1.07:1	-6,16	Dipole	No
M2 2M7	1,28	9,94	2,65	2,26	15,76	3,7	245,0	18,4	16,1	none	204,9	1.14:1	-5,98	T Match	Yes
*M2 2M7	1,28	9,94	2,21	2,03	15,17	3,7	239,9	18,4	16,1	none	204,9	1.14:1	-6,48	T Match	Yes
+KF2YN Boxkite 7	1,32	13,34	4,17	3,40	19,30	5,2	245,5	26,8	23,6	24,5	52,7	1.06:1	-2,40	Dipole	Yes
+YU7XL 8 Hybrid	1,34	10,49	2,79	2,50	16,40	3,2	251,6	19,8	17,1	none	199,9	1.13:1	-5,46	Horiz Dipole	Yes
*YU7XL 8 Hybrid	1,34	10,49	3,00	2,43	16,43	3,5	247,7	19,8	17,1	none	199,9	1.13:1	-5,36	Horiz Dipole	Yes
+G0KSC 7LFA	1,39	10,60	2,84	2,49	16,51	3,7	249,4	20,4	16,1	none	48,0	1.19:1	-5,31	LFA Loop	Yes
*G0KSC 7 LFA	1,39	10,60	2,60	2,20	16,19	3,7	233,6	20,4	16,1	none	48,0	1.19:1	-5,35	LFA Loop	Yes
+EAntenna 144LFA7	1,39	10,58	2,84	2,49	16,50	4,3	246,5	22,5	15,2	none	48,6	1.15:1	-5,26	LFA Loop	Yes
+DG7YBN 7	1,44	10,59	2,88	2,47	16,55	4,5	242,7	23,2	17,4	none	47,2	1.70:1	-5,15	Bent Dipole	No
Vine 7 FD	1,45	10,56	2,83	2,46	16,47	8,2	238,6	22,8	17,9	none	47,9	1.14:1	-5,16	Folded Dipole	No
+InnoV 7 FD	1,46	10,85	2,97	2,62	16,82	3,8	252,1	22,4	14,8	none	47,7	1.26:1	-5,05	Folded Dipole	No
+*InnoV 7 FD	1,46	10,85	2,96	2,61	16,81	3,8	249,4	22,4	14,8	none	47,7	1.26:1	-5,01	Folded Dipole	No
G4CQM 7	1,50	10,76	2,89	2,53	16,69	7,9	239,9	23,5	17,9	none	50,7	2.31:1	-4,96	Dipole	No
+CT1FFU 7	1,54	10,82	2,87	2,50	16,70	2,8	237,7	20,3	18,4	20,4	28,0	1.02:1	-4,96		
DK7ZB 7	1,57	11,11	3,16	2,84	17,13	5,8	272,6	16,9	11,9	16,9	28,4	1.64:1	-5,07	Dipole	No

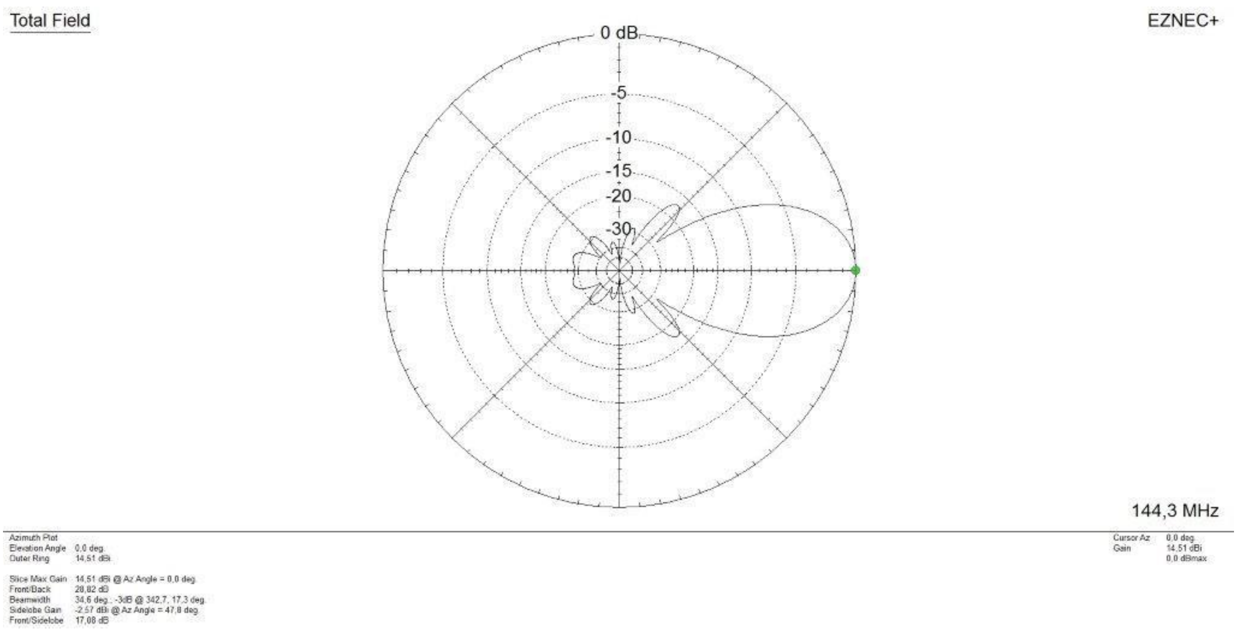
In the following pictures you can see the radiation patterns of two antennas, one the WY209 of WIMO of 9 elements with a slightly older design that gives us a G = 14.64 dBi and a T = 275.2 ºK, resulting in a G/T = -9.76. Another novel design of YU7XL, is a Quagy of 10 elements, with a G = 14.81 dBi and T = 234.3 ºK, resulting in a G/T = -8.8. Note that in near boom lengths, the difference in numbers never exceeds 1 dB, but we are talking about signals that are decoded below the noise several dB.

ANTENNA DK7ZB9 8MM

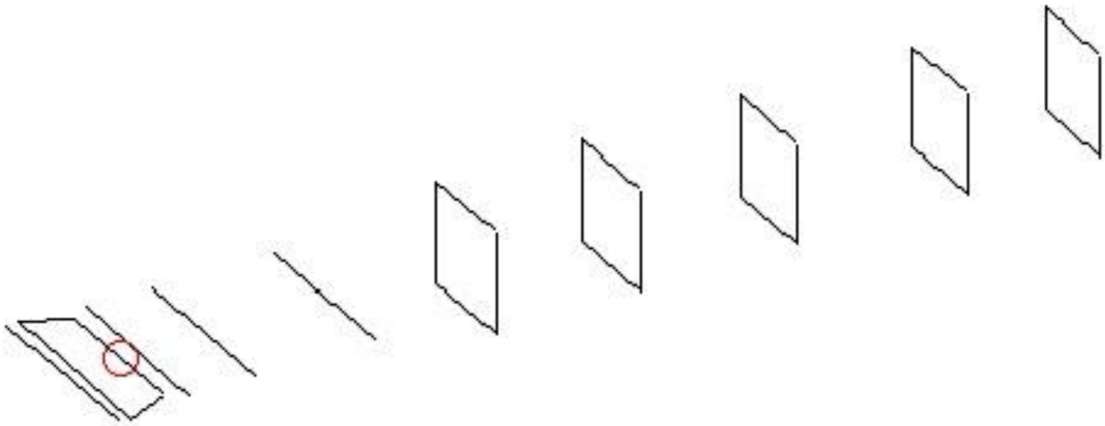


PERFORMANCES:

No of ele	L (mm)	G (dBi)	F/B (dB)	F/Sh (dBi)	F/Sv (dBi)	Hor (?)	Ver (?)	Temp (?K)	G/T (dB)	Tlos (K)
9	4980	14.64	29.12	15.71	11.73	32.2	34.8	275.2	-9.76	4.9

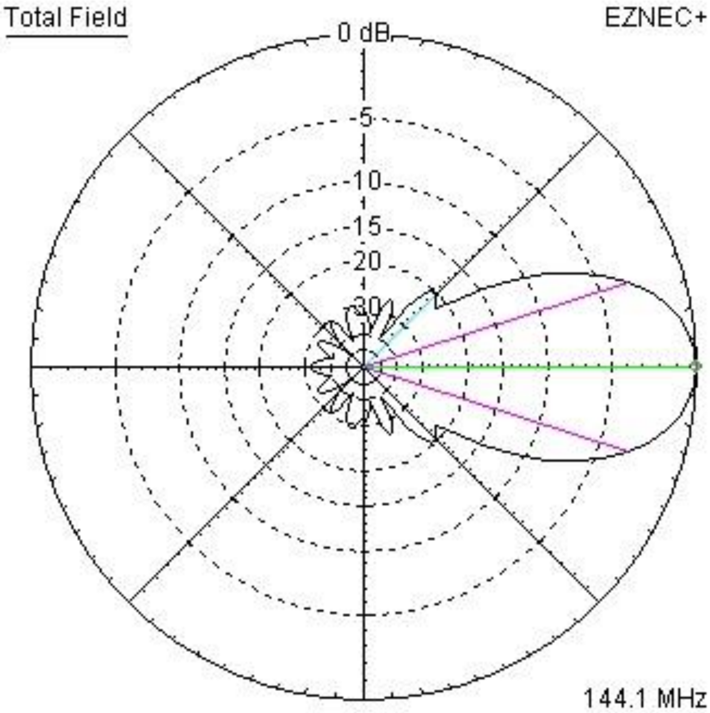


ANTENNA QY21010XL2D5



PERFORMANCES:

No of ele	L (mm)	G (dBi)	F/B (dB)	F/Sh (dBi)	F/Sv (dBi)	Hor (?)	Ver (?)	Temp (?K)	G/T (dB)	Tlos (K)
10	5205	14.81	31.23	20.11	14.93	35.2	37.2	234.3	-8.88	3.5



Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	0.0 deg.	Gain	14.91 dBi
Outer Ring	14.91 dBi		0.0 dBmax
			0.0 dBmax3D

3D Max Gain	14.91 dBi
Slice Max Gain	14.91 dBi @ Az Angle = 0.0 deg.
Front/Back	31.23 dB
Beamwidth	35.2 deg.; -3dB @ 342.4, 17.6 deg.
Sidelobe Gain	-5.2 dBi @ Az Angle = 45.0 deg.
Front/Sidelobe	20.11 dB

Once the noise has already been received, we have to rely on the filters that the manufacturer has installed on our transceiver.

If our receiver is an SDR we still have another tool and it is to install before the decoding program, a filter with open and experimental software very widespread among the community of “lunatics”, that is called LINRAD. Being an experimental software, it is not easy to configure, but it has an outstanding NB.

DOPPLER EFFECT

This Effect, that is really important working satellites, where we have to look for +/- 10 kHz in the 435 MHz band, is not so important in EME, because the Moon moves with respect to Earth much slower than a Low Earth Orbit satellite. Well, it is not very important in 144 MHz, which is only 0.44 KHz, but if it is in 1.296 MHz up where we speak of several KHz.

WSJT decoding programs and other extraordinary prediction programs such as Moonsked, will inform us how many Hz or KHz we have to shift to correct this Effect. Think that the signals are not audible, you have to look for them on the computer screen.

At 1.296 MHz up to the Doppler Effect is added the accuracy of the oscillators, something really complicated in 10 GHz, where many times must be constantly contrasting with a known beacon or a GPS-synchronized pattern oscillator, to know our exact frequency.

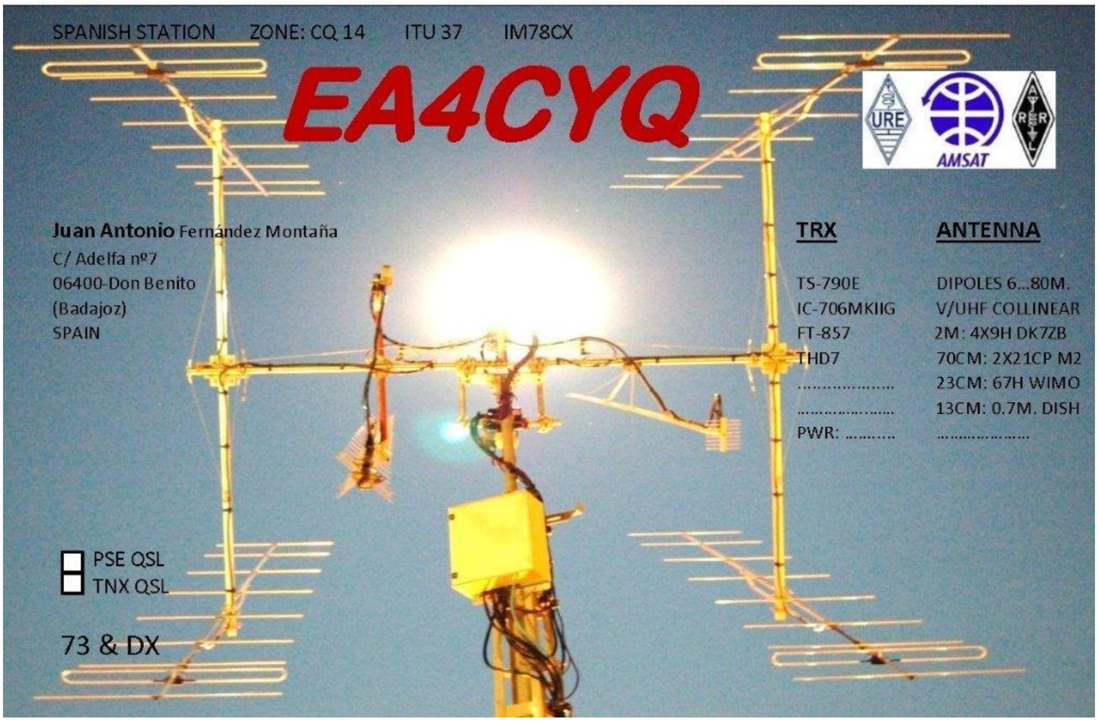
SPATIAL ROTATION AND FARADAY EFFECT

In the previous article we made it clear that it is not possible to know with what polarity we will get a signal that goes through the atmosphere, whether coming from a satellite or the Moon.

But also in EME we have to add sometimes the so-called "unidirectional propagation", that is if I transmit with the same polarity with which I receive a signal, I have no guarantee that it reaches to the other station with the same polarity that he transmitted to me, "Unbelievable!". Let's see what options we have:

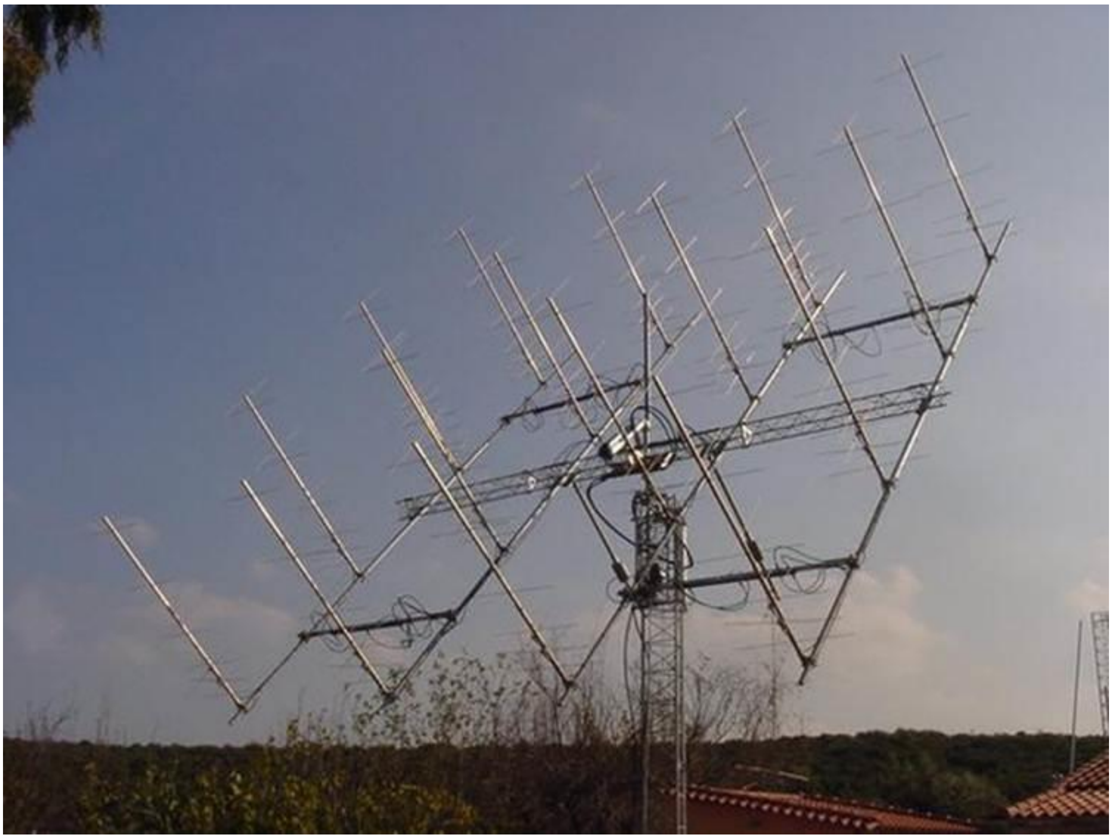
1.- WAIT

That is, as the polarity is changing, we can wait, sometimes a few minutes, sometimes hours, sometimes days, and we will find the right time in which contact is possible. Some of you will tell me What an awful thing!. I do not think so, there are some hams who spend hours and hours listening to the 6 meters and they do not hear anything!.



2.- <u>TURN OUR ANTENNA IN ITS AXIS</u>

In satellites we are accustomed with our hand antenna (IOio, CJU, ARROW, ELK, etc.) to rotate until finding the correct polarity and voilà the signal is coming. Of course, to turn 4 antennas setup is not so easy, in the QSL of JR3REX you can see how it has been engineered mechanically. In bands of 432 up, the yagis are usually mounted by the reflector, rotating its base. Like the set of 16x6 elements of SV1BTR.



3.- INSTALL CIRCULAR POLARIZATION

If all that work 144 EME had circular polarization would minimize this effect, but since most work with linear polarization, when conditions were "perfect", we would be losing 3 dB !!!, it is almost preferable to have a linear polarization and wait.

In bands where we work with parabolic antennas (1.2 GHz), where the polarity is achieved in the illuminator, mechanically is much easier, so Circular Polarization is used in a generalized way.

4.- CHOOSE BETWEEN TWO POLARIZATIONS

We can build our yaguis with the two polarizations, they do not have to be H and V, we can install them in a X shape, to EME and satellites is the same, but for terrestrial communications will we get better results with H and V.

By means of a switch we can choose to receive with one polarization or another, and of course, to TX with a polarization or another. It is surprising when an EME station with two polarizations changes the polarization as suddenly you start to see a perfectly decodable signal, when before there was nothing. You can see the photo of the installation of Maxi EA5CV.

There was a time, especially in the army, where a system that was called "diversity" was widely used, and even a receiver like the IC-PCR-2500 had it installed. It is not usable in EME, because it is not useful in SSB with signals under the noise. It consisted of two receivers, each one connected to a different polarity, so the equipment switched the audio output from one receiver to another, according to which presented more signal.

5.- ADAPTIVE POLARIZATION RECEIVER

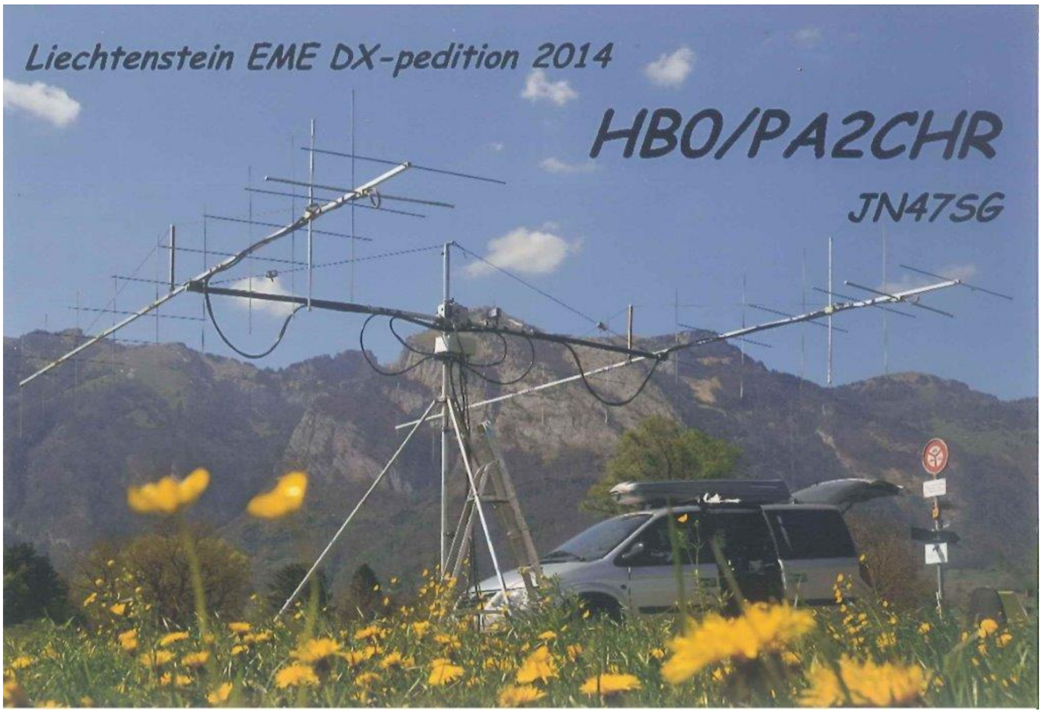
As all the information on this novel system is in English, its translation still sounds strange to us "adaptive polarization receiver". At present, there is no commercial manufacturer that sells SDRs or conventional 144 MHz or higher frequency equipment that has two identical and in-phase receivers, that is, with the same local oscillator. In HF the famous SDR FLEX-xxxxx are not in phase, and in conventional brands, the only one that has them in phase is the Elecraft K3, with which you can use transverters for the high frequencies.

The only equipment that fulfills these characteristics is manufactured by Alex HB9DRI and is called IQ +, for now it is manufactured as a receiver, and it will transmit in the near future.

This novel system, with an antenna of two polarities, can receive just as well any signal in any polarity, and even informs you of the polarity with which it is reaching you. The reality has shown that this system is capable of receiving 80% more stations than with a single lineal polarity.

To transmit we will have to choose to do it with a single polarity, H or V. Some stations choose to transmit with circular polarization.

To give you an idea of its effectiveness, Atletico Team formed by PE1L, PA3CEE and DL2NUD in its recent expedition from May 2014 to Senegal as 6W/PE1L, with 2 yaguis of only 8 elements (4.5 meters of boom), both with Polarization H and V, connected to an IQ + and a 1kW amplifier, has managed to make 455 different stations in less than 3 weeks, setting a new world record for a portable expedition in EME.



SUMMARIZING

EME is difficult, yes of course, surely the biggest challenge we can propose, but I wanted to convey that it is possible. Today, taking advantage of the protocol for weak signals WSJT, reading a lot, with two discreet yagis and if you want to face something different, you can make contacts every day of the year, around the world. Without depending on the solar cycle, the ionosphere or a satellite. The moon is there every day, about 12 hours.

And I can assure you that hearing or seeing on your PC screen a signal coming from the Moon, from a portable station with two antennas less than 5 meters in length from anywhere in the world, as recently as KH8/ZL1RS, is hardly comparable to other challenges that I have reached, such as making contacts in voice (FM), with 3 different ISS crews.

I hope to see you on my screen and that you feel the MOON A LITTLE NEARER.

EA4CYQ
Juan Antonio Fernández Montaña

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