A Moon Bounce Experiment With A 32m KDDI Cassegrain Antenna And A Special Station 8N1EME

Mike Watanabe, JH1KRC
Project BIG-DISH 2007

< The First Approach >

One day in June, 2006, a local newspaper of Ibaraki Prefecture revealed an unexpected plan that KDDI satellite center would close their operation by the end of March 2007. This scoop was spread immediately by a local moon-bounce operator, Kony Nemoto, JM1GSH, through the JA-EME network.

A proposal was initiated in a few weeks; how about amateur radio moon-bounce experiment using a huge dish antenna of KDDI? Next month a group of Japanese amateur radio enthusiasts met for their special planning at KDDI-Ibaraki Satellite Communication Center in the Grid Locator QM06, Takahagi City, Ibaraki, Japan.

Some twenty amateurs had the first EME meeting at KDDI Ibaraki, July, 2006. IBA-5 in the back.

This Center was built as a communication node for Intelsat and Inmarsat services, and has several immense parabolic dish antennas and associated infrastructure buildings for administrative, research, construction and maintenance purposes.

KDDI offered IBA-4 32-meter cassegrain reflecting dish was offered for radio amateurs' moon-bounce.

Yuki Uchiyama, JH1NBN, a well-known DXer and an active DXpeditioner, and also a good friend of Mike for years, was one of the first persons to contact with. Yuki presently works for KDDI and had a carrier at the Center years before.

By that time, not all of KDDI antennas were in active service; some already being in stand-by mode. This situation made Japanese radio amateurs possible to plan a historical moon-bounce activity. Along with an approval, a favorable offer from KDDI was given for the creation of radio amateurs' "Big Dish" project to communicate on the usual amateur frequencies via the moon, using IBA-4 32-meter cassegrain reflector dish antenna, one of the KDDI's main antennas.

A special taskforce consisting of Japanese radio amateur moon-bounce enthusiasts was formed to solve technical and logistic problems associated with this project. Later, engineers from Czech Technical University in Prague were invited into the team for consulting and designing of the primary antenna feeds for amateur frequencies.

Yuki and Mike had talks with KDDI stuffs and engineers from Mitsubishi Electronics Co. who are responsible to maintain this antenna. Mike felt that the first approach was well-done and close to the success. Later, a president secretary of KDDI told us that one of the vice-president of KDDI strongly supported our activity. She was so clever to have had submitted our document of the EME plan to the vise-president, which must be the first key to open the door of success. TNX!

<Project BIG-DISH>

Some twenty JA-EME amateurs conformed this project, naming it "the Project BIG-DISH". They began to discuss how to proceed the experiment through an email network, as well as a web-site of the Project, constructed by Bunshiro Tamura, JA5FNX, who also maintains JA-EME web-site for many years. Those enabled the Project BIG-DISH to work on solving the many problems associated with launching its station on the air before this KDDI Center totally closed their operation within a half year.

We thought there had to be some specific reasons in this case to approve for the special EME license. The purposes to use this antenna for the moon-bounce aimed the following:

- A precise, large-scale antenna is used for amateur's advanced EME. (A professional antenna was formally used for the first time in Japanese history of radio amateurs, not only for the EME, but also simply for radio amateur transmission!)
- EME contacts to small stations are intended.
- EME exhibition to radio amateurs.
- Scientific exposure to young generations such as school children and technical school students.

KDDI and the Project members are willing to invite

audiences to come and see our EME communications, as well as to attend the lectures on space communications and history of this Center which is thought to be a milestone of Japanese international telecommunications. We named this activity as a Moon-Bounce Class Room under the BIG-DISH.

No one of the EME project members doubted this activity would become a milestone of Japanese radio amateurs, too.

<How to get the licenses>

In the middle of December, 2006, the Board Directors of Japan Amateur Radio League offered the Project for the support to obtain the special license. JARL, KDDI Corporation and the Project BIG-DISH formally signed for an experimental cooperation using KDDI's 32-meter Cassegrain dish antenna.

The special EME licenses were approved to the Japanese governmental Bureau of Telecommunications for the maximum high power output of the legal-limit. The experimental EME operation was planned on the usual EME frequencies, such as 144, 432, 1296 and 5760 MHz bands, in CW, SSB, and JT65B modes. On each band we requested 500 watts of output power to achieve huge hundreds of kilo-watts, or mega-watts, EIRP. Such an extraordinary high power was intended to make our signals easy to hear by small antenna stations off the moon. This license was issued in a few months after several serious exchanges of opinions with Telecomm officials. But 5.7GHz license had to be approved separately; because our 1296MHz dish feed totally covers an opening of the original feed horn used for 5.7 GHz operation.

In the Japanese traditional telecommunication administrations, even for radio amateurs, you cannot preliminarily apply for, or cannot obtain an operation license for the bands and/or modes which you cannot actually transmit when the license is issued. Someone from the Bureau of Telecommunications would come and see what should be going on in your radio station every time before the license being issued. If your transmitter of a certain band is still under construction, you have to apply for the license another time for this transmitter and for the band, again. How silly, but it's a real system! If you move your QTH, or you increase the output power from 50 watts, for example, to 100 watts, you have to do the same as above. For what?

After negotiation with JARL and the Telecom, we were fortunate to obtain a special callsign 8N1EME for this event, representing the EME activities by a special licensed amateur station. In Japanese radio amateurs' history, this became the first time to operate from the commercial site using the professional antenna.

< About IBA-4 Antenna >

The IBA-4 (pronounced like *iba-yon*) meaning the 4th antenna of the KDDI Ibaraki Satellite Communications Center, is one of the main cassegrain antennas. It was originally designed for the satellite communications in C-band, between 4 and 7 GHz satellite band. This

antenna has the weight of 380-tons without wind load, the height of the elevation hinge at 25 meters above the ground, is fully rotatable about 370 degrees in azimuth, and can be elevated up to 110 degrees. These specifications are undoubtedly suitable for amateur's moon-bounce communications. Automatically programmed moon tracking is also available by the original minicomputer, using punched-out tapes. The nominal mechanical accuracy is within 0.02 degrees each. You would input the moon data of every 30 minutes, so that the minicomputer would calculate and almost smoothly compensate the moon path of every second. F1EHN's program was used to obtain the data of the moon orbits.

No one doubted that we were sure to use this original antenna system for 5760MHz successfully; since IBA-4 had both right and left circular polarization wave-guide feed lines, and good pass-band characteristics for our band as well. There were a couple of 3kW TWT amplifiers in the antenna pedestal room where our shack is located, but we were not allowed to touch them.

< Antenna Modification >

The largest problem we met was that the cassegrain sub-reflector, 2.9 meters in diameter, about 9.6 meters in front of the main reflector was not able to be removed. The primary focus of the main reflector is far beyond the sub-reflector vertex. According to the agreement with KDDI it was strongly prohibited to remove even a single bolt or nut from the present antenna. Therefore we had to drive this sub-reflector in some way to illuminate the main reflector for the EME operation. The actual size of the sub-reflector, 2.9m, seemed to be too small as a cassegrain reflector for 70cm band, but large enough to decrease the antenna gain by the mal-positioning of the feed point for the primary focus feed to be used.

Yoshiro JA4BLC and Yoshiyuki JA6XKQ were so helpful to advise how to think about the dish feed position, but had no enough time to solve all the problems in the antenna modification.

Rastislava (Rasto) Galuscak, OM6AA, and Mike began to talk about the antenna feed design. They continued to exchange over 250 email correspondences

discussing the proper and possible feed designs. There was no time to exchange one feed model to another for comparison. The electrical and mechanical modifications were once designed and built, we had to use them till the end of the operation. This means there was only one chance for the success.

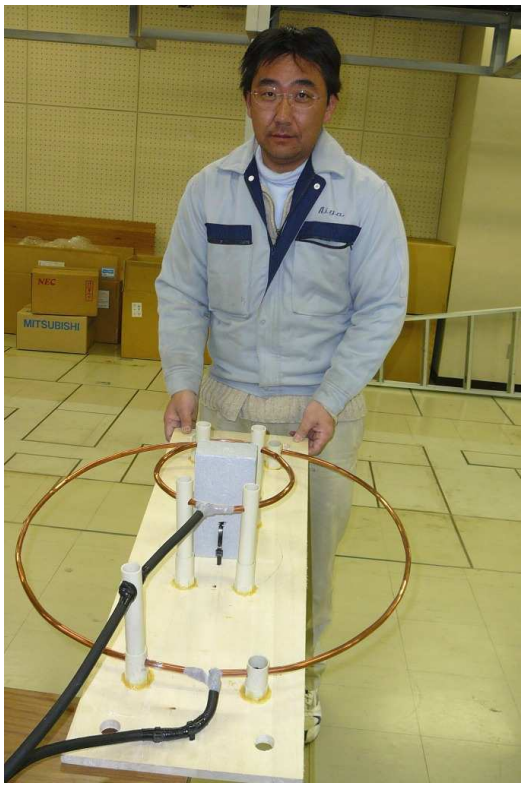
Problems we encountered and the solutions concerning to the design of primary feeds were later described in the DUBUS magazine, No.4, 2007. The Japanese translation of this article was published in the Japanese CQ ham radio magazine, November and December issues, 2007.

With a great help from Rasto our feed design for the IBA-4 modification reached to the conclusion. It shows the antenna gain of **28.5dBi** on 144MHz, **34.3dBi** on 432MHz, and **48.5dBi** on 1296MHz. The original IBA-4 antenna would make it **64.8dBi** on 5760MHz without changing the feed. The beam-widths of 1296MHz and 5760MHz are 0.2 degrees and 0.1 degrees respectively, narrower than the optic angle of the moon, ca. 0.5 degrees.

< The Hard Days and Nights >

The mechanical construction for modifying the antenna feeds for the EME operation was planned in early February, 2007. The taskforce members who owed to build up each of the actual antenna feeds and the associated parts had to make it ***hurry***. Mike JH1KRC had to brush up a 2.4m US army surplus dish, prepared for 1296MHz. Shigeru JH1EFA created the arms to hold a substantial round septum feed, made by OM1ATT, accurately in the focal position, and well-designed dish holders to fix this army dish on the tip of original horn aperture in the center of the 32m main reflector. (If it would drop off or slip away, we had to compensate all the possible damages to repair.)

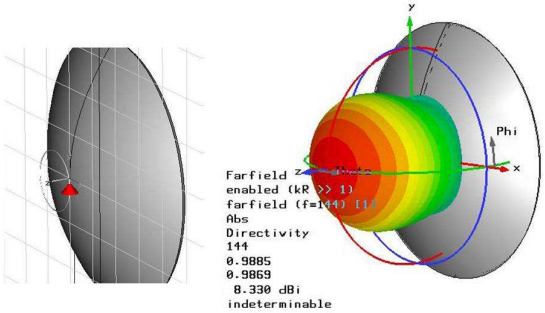
Koichi JJ1NNJ built up a water-proof box of plastic material in which LNAs and relays for 144/432 MHz were installed. Noriyuki JH0WJF, who often wins in the CSVHF noise figure contests, had prepared LNAs of very low noise characteristic for 432 MHz.



Kony JM1GSH holds 2m/70cm loop feed.

A unique two-band loop feed was designed by Rasto, and built up by Mike without using any metal material except for the 10mm copper tubings and thick coax

cables. Mike had to make it after he returned to his dormitory late in the night. Fortunate enough he had no claims from the neighbors to the noises of drilling, hacksaw, and hummer Mike made nearly in the mid-night.



144MHz 凸面鏡付きループの放射特性

Radiation pattern of 2m loop feed reflected from the original sub-reflector of IBA-4 used as a ground plane, a trade-off for the 2-band feed.

Along with antenna feed construction, Kony, Mike and Shuko 7M2PDT had to be involved in the documentation work and spent for hundreds of hours to obtain the EME operation licenses.

Early in the New Year 2007, we got ready to submit a volume of documentations including the transmitter design and block diagrams, specifications, the methods and data of spurious suppression, etc. The telecom officials were so kind to request us, in addition, to submit the detailed explanations on the calculated antenna design, and the moon-bounce link budget for each band. And they also kindly requested us to show them the radiation characteristics of our modified IBA-4 antenna, in order to see whether or not our antenna beam patterns and transmission power would satisfy the present radiation hazard control and safety regulations. It was not a surprise; Japanese telecom uses to request amateurs to submit these documentations for a common amateur radio licensing (especially for high power, or for EME). If you can submit them, they would issue the license, and if not, the license would be impossible.

Fortunately the KDDI's communication site already had, from the beginning of the history, been located in an ideal place for space communications on an isolated hill-top without so many neighbors. Later, at least Kony and Koichi visited two neighbor families who live next to the site, to inspect if they had any TVI, they welcomed these unusual guests with great pleasure.

< Antenna Construction >

Not only the local amateurs like JA1BGU, JK1KXH, JH0XHL, JE1BNZ, etc., our friends from far places, JA0TJU and his son, JA7AGU and JH7SIA came to help us. Cable placement through the rotary sections on the antenna hub and pedestal was a hard job, but finished very smoothly by these experienced amateurs.

We hired a heavy crane lift of 50-meter, 2-ton, which was costly, 120k Yen for each day, but it enabled the antenna construction really prompt, safe and pleasant. Every heavy or large material was put in to the IBA-4 dish surface by the crane lift.

The 2.4-meter military dish was put in and fixed onto the horn aperture with 6 pcs. of well-designed clamps. 2m/70cm loop feed was hang up by the professional workers. The suspension ropes were pulled like “marionette”, and tied up so that the loop feed was fixed in the proper position.

The climate of this Pacific Coast in Eastern Japan in winter seemed to be very fine, warm enough and clear. All construction procedures necessary for our operation ended only in four days without any trouble. So it was the time for the “marionette theater” open.

<Never Imagined the 9th Harmonic Radiation>

After the antenna construction was finished in the mid-February, 8N1EME began to test transmission to avoid any interference to the satellite communication equipments here and around. Our transmitters were equipped with harmonic filters and had cleared the harmonic suppression of -70 dB. When we test-transmitted 432 MHz, an engineer in the KDDI operation room phoned us that their C-band receiver equipped in the same room as 8N1EME detected the very strong 9th harmonic on 3888 MHz. His voice was vibrating, express full of anger (or fear?). The receiver was connected to the wave-guides of the same antenna that we used. (It means they do not use this C-band

system. Why didn't they turn off the receiver? Actually, they cannot.) We had never imagined that we had to suppress the 9th harmonic from Henry amplifier down to undetectable level to the C-band high gain receiver on the same antenna, but we tried it. HP spectrum analyzer was no use; because the harmonic level was already too low in the display.

1296MHz transmission was more severe in this situation to suppress the 3rd harmonic onto 3888MHz. Precise coaxial band-pass filter helped a lot, as well as the HPA unit we had employed, using 8xFLL300IL2 GaAs-FET's operating in the class AB, but the 3rd harmonic did not totally disappear. Finally they abandoned it, and the harmonic problem was totally cleared up. They now understood that their C-band receiver, with its horn aperture being wholly covered by our 2.4m dish, received with its full-gain. So far we were lucky that we did not burn the KDDI's expensive receiver!!

<Strong was GaAs-FET>

In the evening one day before the telecom inspection, everything went on well until the moment when Mike was tuning the power hybrid in the 1.2G HPA output for the final adjustment. A send-key cable of HPA dropped off and came into the gate bias power supply. It badly shorted a high voltage section of the gate bias circuit, and several hundreds amperes of drain current flew. It was fortunate this GaAs-FET amplifier did not get any damage, except for all the IC's in the bias supply, and the T/R change-over sequence circuit totally got short.

At that night, the T/R sequence circuit had to be built up for replacement with ordinary mechanical relays and capacitors, and the gate bias supply had to be changed to another in the bath room of a local hotel where Mike stayed. The brightest area in the hotel room was the bath room. Putting the toilette lid on, Mike sitting on it, the repair was finished well in time for the telecom inspection to begin from 10 a.m. the next morning.

Testing the 1.2GHz GaAs-FET HPA installed in a water-proof box after the over-night repair. JH7SIA smiles in the pedestal room of IBA-4.

<License Is Issued>

February 23, the EME station was inspected by the people from the governmental telecom for the operation license to be issued immediately. During the inspection 8N1EME was asked to have a contact

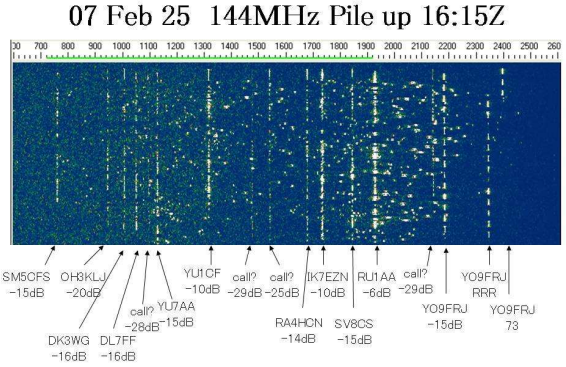
via the moon. The very first but pleasant EME contact was made with JA6AHB on 432 MHz CW. This ***ceremony*** was performed by Koichi JJ1NNJ.

Our EME operation began in the afternoon of February 23, first on 432MHz, and other bands followed. The operation was very limited in time because most of the amateur operators live far from the KDDI Center, and only limited number of KDDI stuffs could control the IBA-4 antenna. We were ***not*** allowed to come in to the control room, so we had to choose the operation dates, mostly on the weekends when the moon conditions were favorable, and ask KDDI stuffs to work with us during the moon time for the days/nights. It lasted until the end of March in 2007.

<How the bands sound like?>

Shuko 7M2PDT and Koichi JJ1NNJ were the main operators for 432MHz. For this band, the antenna efficiency was calculated to be only 13 % because of the defocused position of the loop feed. In order to make IBA-4 a tri-band antenna, this was a compromise we chose. Still on this band total antenna gain was 34.3dBi, not too bad. While Koichi operated CW, Shuko did mostly JT65. It seems they worked out almost all the stations on the band, and finally there was no station calling at all.

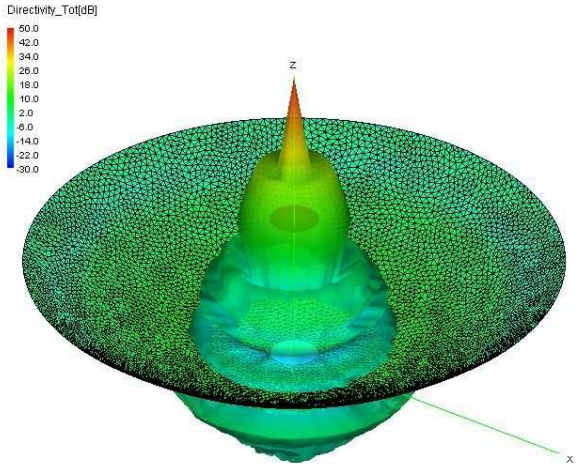
Defocusing caused certain gain loss on 144 MHz also, but the degradation was not so much as on 432. The antenna efficiency was 31% and the total antenna gain was calculated to be 28.5dBi, which should become one of the largest antenna on this band. Even an SSB echo was clearly heard. Kony JM1GSH, Yasu JH2COZ, Hide JH5FOQ, and Shiro JH0MHE enjoyed mostly operating JT65, also many QSO's in CW as well. See the ***dog pile-ups*** in the screen shot. It lasted until the ***last*** moon set.



このような大パイルアップが、17Zの「月の入り」まで続いた

A unique triple reflector configulation on 1296MHz worked quite successful. 2.4m Army dish with a round septum feed, made by OM1ATT, illuminates the sub-reflector to achieve the edge taper of 11dB for the highest antenna efficiency on this band. This made the total antenna gain of 48.5dBi on 1296MHz.

There are several 23cm op's who pushed our S-meter to the red zone. But in this time, the strongest echo was that of 8N1EME, perhaps +10dB or more.



This configulation provided a very low noise temperature characteristic. Rasto wrote; For the Earth temperature T0=290K, the noise temperature of this antenna calculated at the elevation angle 5 degrees would be 35K. As the elevation becomes 20 degrees, the noise temperature would be 8K or so, which is very suitable for EME communications.

But such low noise characteristic sometimes might give misunderstanding. Once we found the signals and the noise suddenly came down, and only very weak echo of 8N1EME was audible. Our receiver became very quiet. It used to hear our echo with S9++, and several dB's of the moon noise during our operation. So we thought that our LNA, NF=0.2dB, made by HB9BBD, had to be badly damaged. It happened in the ***culmination*** hour.

The next morning we checked our whole system, but found nothing defected, except for the antenna positioning at the moon in the meridian passage when the IBA-4 tracking program did not calculate the moon position exactly, just about 0.5 degrees away.

Unfortunately in the first few days we had no microphone, but mostly on 1296MHz, both SSB and CW sounded very loud and comfortable like 20-m QSOs.

< Moon-Bounce Class Room>

March 3, 2006, there held an open-house exhibition and lectures to 150 audiences. The Project asked to people who would like to join our event on the web site, first limited for 100 seats. Only one and a half days was needed to full-fill the seats. So we had to increase it to 150. But one more day was enough to stop reservation for the seats.

There held lectures on satellite communications, and on the history of this Communication Center by

KDDI stuffs, and on amateur's EME by JH2OZ, and about the Project BIG-DISH by JH1KRC.

After the lectures, from 1730 local time when the full moon was at 5 degrees elevation in the east, the special ***Moon-Bounce Class Room under the BIG-DISH*** was held on 1296MHz, SSB.

Audiences were surprised to listen to the strong echoes of 8N1EME, and those of U.S. cooperative stations like K2UYH, K5JL and K9SLQ. School boys and a girl came to the operation seats, and their names were announced by Mike. U.S. attendants came in to say hello to the school children. These events were broadcasted by NHK network world-wide.

Among the children there came a boy of 11 years old who told Mike that he has the First Class amateur operator license. Mike asked him, "Really?" four times, according to the boy's father. Mike immediately changed the operating position to the boy, Hirotomo Nakamura, JQ2LVT. Hirotomo contacted with K5JL, which could be an EME contact by the youngest amateur all over the world.

Our low bands operation ended soon after the moon set of early morning, March 5. We had to dismount all the antennas from IBA-4, so that we would prepare for another licensing for 5760MHz. If we had missed that day, we could not have got ready for it. As soon as we finished disassembling all the antennas before 11 a.m., suddenly a very bad storm began with strong winds and heavy rain. We were saved again.

<5760MHz>

How could you expect the signal strength of ***1,200,000kW EIRP*** off the moon? Soon after we got the license of 5760MHz with this EIRP, possibly the highest EIRP (63.84dBi, 500 Watts TX output) in the amateur's history, we had to wait for the moon-rise in that night (because we drank so much for the cerebration, and could not go home). We transmitted for echo testing for the first time on this band, only for a minute. A weak echo was heard. We found our LNA/converter gain seemed too low. But it was surprising; there came an SWL report from Charlie, VK3NX, that our signal was very strong but had remarkable frequency drift. Yes, we had some incidental frequency drift, and we moved the transmitting frequency manually to tune to the HP frequency counter!! Mike took back the LNA's and repaired with new FHX-35LG's.

Our final operation began on 5760MHz in the morning of March 24. Our echo became very strong

with the LNA's, one repaired, and another one from JA6CZD. We were lucky to find W5LUA testing. 8N1EME began to call CQ near Al's frequency. He replied soon.

Al wrote, "There was a very strong signal on my frequency. It was stronger than any other EME signal on any band that I have ever heard. I was blown away!!" Al thought it should be his local station. We exchanged the signal reports of 599's each other.

JA4BLC, JR4ZZS, JA6CZD and JA8ERE followed for their fist EME QSO's on this band.

In the night, Europe window was very busy for the DUBUS Contest. Most of signals were really strong, S9+, S5 to 7, etc. Among them there was a weak signal calling; GM4ISM with 449. He gave us 559 for the first GM(or Great Britain)/JA contact. His antenna was 1.8m dish, specially prepared for this contact.

The next day Al tried to hear us with a horn antenna of 27cm aperture, and he did hear our signal partially. The last two QSO's of 8N1EME operation were shared by VE4MA and WD5AGO on this band. 8N1EME sent TNX and 73 by Mike at 0509UT, March 26, 2007, and went QRT from EME.

<EME with Small Antennas>

According to the calculation of link budget we presumably made, 8N1EME had to have contact to small stations. We succeeded to work some of such stations with small antenna and small power on 144MHz and 432MHz, like JF1DMQ with 2-yagis, 45 watts output on 432MHz.

Since hundreds of microwave enthusiasts were active in Japan, we asked them to listen to our EME operation on 5760MHz. Several SWL reports came in; most of successful receiving were done with small dish antennas, from the size of 45cm to 300cm. Larger dishes like 2m, or 3m sizes were tried in some cases but it seems for them to be more difficult to hit the moon. According to the link budget we calculated, 8N1EME might have a QSO with 2 watts output (Japanese legal-limit for ordinary stations) into a 4m dish on 5760MHz, but no one did it.

There still remains a question that a station with large scale antenna, whose beam width would be much narrower than 0.5 degrees, might have certain degradation in receiving power. Unlike we aimed at the beginning, this question was not clearly solved yet.

Project "SMALL-DISH" by JJ1NNJ at 8N1EME-sitre during the 5760MHz operation

<Final Results>

Total EME QSOs: 323

144MHz: 154 (CW 11, SSB 1, JT65 142)

432MHz: 57 (CW 34, SSB 2, JT65 31)

1296MHz: 71 (CW 50, SSB 21)

5760MHz: 31 (CW 31, SSB 6, CW/SSB)

Non-EME QSOs: 11,500 on HF/VHF/UHF/Satellite by local amateurs.

<EME Stuffs>

Project BIG-DISH Board Members:

JH1KRC, JM1GSH, 7M2PDT, JA1BGU, JA5FNX, JE1KFX, JF1AKD, JH1EFA, JH6RTO, JJ1NNJ, and JR0XHL

Associate members:

JA0GPT, JA0TJU, JA1BAX, JA5NNS, JA6EET, JA7AGL, JE0DKR, JE1BNZ, JE1JKL, JH0MHE, JH1NOT, JH1TVZ, JH1XUJ, JH2COZ, JH5FOQ, JH7SIA, JK1KTY, JO1LDY, JO7MJS, JP1NWZ, JQ2LVT, and JR1PJH

Advisors:

7K3LGC, JA2TY, JA3MKS, JA3SGR, JA4BLC, JA6AHB, JA6CZD, JA6XKQ, JA7JJN, JA9BOH, JF3HUC, JS3SIM, JG2BRI, JH0WJF, JH1WLK, JH3EAO, JH3ERQ, JH5AKH, JJ3JHP, JR3JLL, CT1DMK, K2UYH, LA8LF, OM6AA, OM1ATT, and P. Hazdra

QSL Manager:

JH6RTO/1: Seiji Fukushima, Bellflower 2506, 1182 Hase, Atsugi, Kanagawa 243-0036, Japan

<Many TNX> Go to:

Yuki JH1NBN and other stuffs of KDDI Corporation, the stuffs of Japan Amateur Radio League, and the dedicated officals of the Bureau of Telecommunications, and Ministry of Internal Affairs.

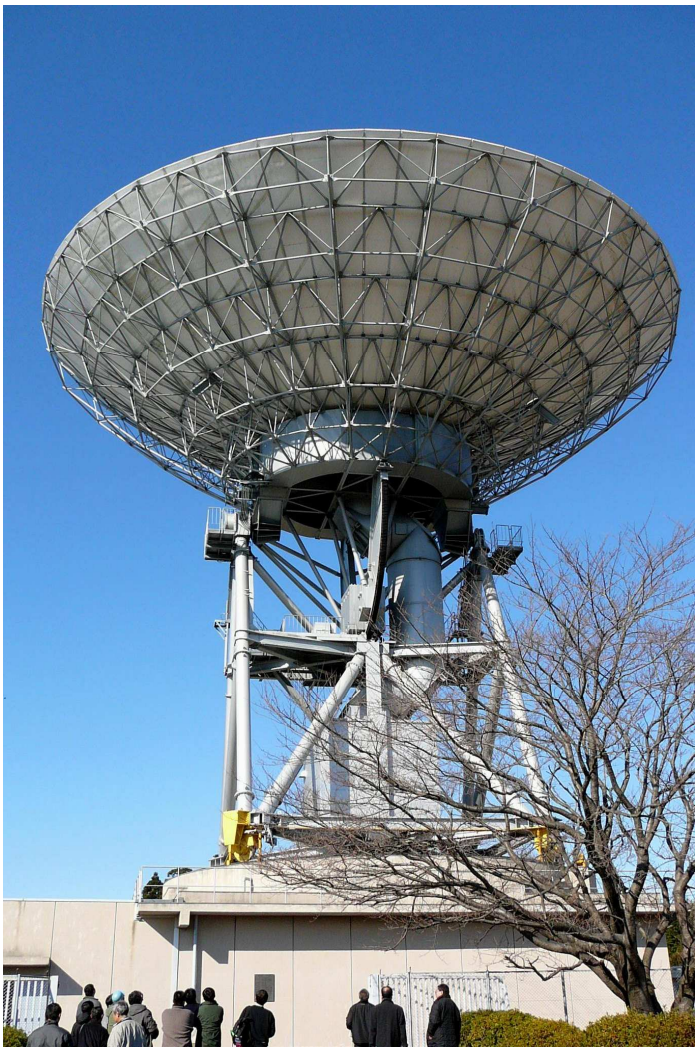
<Web-site>

The Project BIG-DISH 2008, 8N1EME

http://8n1eme.jp

Japan Amateur Radio League

http://www.jarl.or.jp/



IBA-4 antenna is now rebuilt to be a radio-telescope for VLBI research.