Series - Satellite Commentary –

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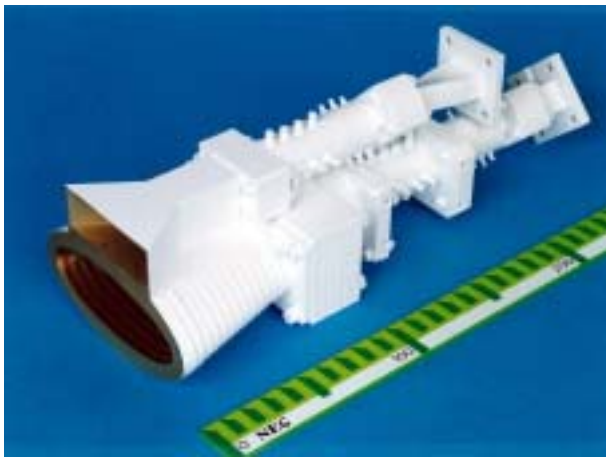
The inside story of Onboard Antenna Development on BS-3 satellite

My name is Tomoki Obuchi, Editor of Space Japan Review. It becomes 2nd Satellite Commentary following the number in August/September (No.24) 2002 In this number, I introduce about the development inside story of the primary feed horn of the Japanese broadcasting satellite 3 (BS-3) onboard antenna. It had been started in November 1985 that the order of the development of the BS-3 onboard antenna came to the place of me. To develop this antenna, it was realized by the effort of several NEC engineers with the cooperation of NHK Science and Technical Research Laboratories, and also the cooperation of NASDA. The requirement to this antenna was that direct satellite TV reception (DTH) was obtained by a small antenna from 40 cm to 60 cm in all areas of Japan from the geostationary earth orbit (GEO) of 110 degrees of east longitude.



The field of view (FOV) over whole of Japan in the GEO is 3 degree x 2 degree, but Ogasawara islands was adapted common reception system by the large TV antenna because of isolated islands.

▲ **Figure –1 BS-3 primary feed horn**

Down side: Corrugated horn, Up side: Rectangular Horn

Then, The FOV requirement of main beam was 3 degree x 1 degree. We thought of loading the offset parabolic antenna on the earth side plane of the GE-3000 bus, and so the antenna was adopted less than 2 m **ϕ**. As a result of the cut and try attempt analyses, the antenna was adopted 1.7m x 0.8m of the elliptical offset parabolic solid reflector and in order to get the optimum illumination efficiency over the reflector, an elliptical corrugate horn was adopted. The aperture of Elliptical corrugated horn is an elliptical form and the inside wall of horn consists of concavity and convexity tooth row as shown in figure -1. The idea was ingenious but I did not have an idea how to analyze the illumination characteristics of the elliptical corrugated horn, and how to realize the hardware.

I ensconced myself in the library, and examined many literatures. I found out that the illumination could be analyzed by Mathieu's equation. However, I was troubled over how to

enter the Mathieu's equation into computer program because of an expert of mathematics, and I asked my boss's advice on the concerns. He was an expert of mathematics, and he agreed willingly with collaboration. In those days, we used the FORTRAN programming by super-computer for an antenna analysis, but the antenna analysis of cut-and-try method by super-computer was required too much cost. He bought an expensive personal computer (PC) with a dot printer at home, and he inputted FORTRAN programming of the Mathieu's equation into the PC. After he returned home, everyday, he inputted several kinds of parameters on elliptical corrugated horn into the PC, and I was reported the output results at the office, next day. The PC in those days had small memories and slow CPU. Then, every time, after the one parameter's computation ended, the dot printer was printed out the results with generating the big sound as well as old typewriter. Also, the analysis to get the results was needed to take more than 10 hours. He continued to compute while going to bed.

▲ **Figure –2 BS-3a/b GEO Image (Courtesy of NASDA)**

Therefore, he received much pestiferous claims from the next neighborhood and also asked to stop from his wife, too. But he wasn't discouraged by it, too, and continued it. The illumination pattern of the correct primary horn was gotten by his support, and it could input to the elliptical offset radiation pattern analysis. I think that it was impossible to get correct antenna radiation characteristics if he did not undertake. The difficulty of elliptical corrugated horn is to have the different depths of the major axis and the minor axis in each aperture size, and also transform the each depth from the aperture plane into circular wave-guide, smoothly. Therefore, I memorize the analysis spent for nearly 1 year to find this optimal size. Moreover, the following unreasonable demand occurred. It was how to manufacture the horn. We examined two methods that one was the lost wax method and another was the 5 axis precise lathe by computer control.

In the manufacture of corrugator’s tooth, the lost wax was not clear-cut of the tooth, and then the lathe was chosen. I decided to order of manufacturing to NEC Tamagawa plant, because there were many experts of TWT manufacturing. The mono-block cast part length of corrugated horn was around 100 mm, and the connection port into circular waveguide was only 15mm diameter. The milling from aperture part was done over hanging turning tool, and then, in the cutting of near the connecting port, it was almost defective products by

blurring. It made nearly 100 units and only three units completed. I was torn between production cost UP and the appointed date of delivery, every day. However, the antenna radiation efficiency was achieved more than 70 % by this horn, fortunately and BS-3a was launched in 1990 and BS-3 b was launched in 1991. The subscriber was immediately done in 3,000,000 within the country and at present, it is hearing that is taken over 14,000,000. It was the story of more than 18 years ago from now, but I think that teamwork, an ardor and pride of young engineers achieved it. When taking charge of the hard-wear, it is failure's continuation but also the pleasure when completed is beyond words. I introduced an anecdote about the antenna development in the youthful experience.

Thank you