ELECTROMAGNETIC CIRCUMSTANCE OF A TEST FACILITY FOR MICROWAVE EXPOSURE EXPERIMENT TO SMALL BIOTA

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Introduction

Biological and ecological effects of microwave illumination should be investigated and evaluated before we will start Solar Power Satellite program. A microwave exposure(ME) facility was built in the area of the AIST Tsukuba Second Research Center for the purpose of the research of the effect on small creatures due to the microwave irradiation for a long time. In the experiment, some microwave energy which is radiated to the open field around an antenna will be scattered to a large area. Therefore, an electromagnetic shield surrounding the irradiated area was made for the safety of the circumstance and staff of the measurement in spite of the low power density.

Electromagnetic condition of the circumstance was measured and evaluated in comparison with the Japanese guidelines on safety of exposure to radio frequency electromagnetic field and the Japanese regulation of radiowave.

Microwave exposure facility

The ME facility is located in the AIST Tsukuba Second Research Center as shown in Fig.1. The area of the research center is about 1400m by 480m including a mobile test course on the circumference. There are some research facilities inside the area, one of which is the ETL building. The ME facility was built near the building due to the utility of electric power supply. Microwave energy is transmitted in the facility and the antenna is put toward the right upper direction. The distance from the antenna to the end of the area along the transmission direction is 585m. The distances to the circumference are shown in Fig.1 and even the shortest distance is longer than 100m.

The structure of the ME facility is shown in Fig.2 by a top view. A microwave power source is a magnetron which is connected to a horn antenna illuminating the ground at an incidence angle of 30 degree. The irradiated area is surrounded by metal meshed net(large mesh) for security and by small meshed net for shielding. The enclosed area is 8m by 8m and the height of the net is 4m. The upper side is left opened for sunbeam incidence. The size of the small mesh is about one thirtieth of the wavelength of the 2.45GHz microwave.

The ground inside the facility is bare or naturally vegetated. The ground condition is retained as it has been for 15 years after the construction of the research center.

Microwave radiator

A magnetron for electric ovens is used as a power source. It is driven by a stabilized 4KV direct current power supply. The output power is variable from 100W to 900W by adjusting the load current. The spectrum of the output signal is shown in Fig.3. Fig.3a is a spectrum observed by a spectrum analyzer with a short sweep time of 50ms. A single spectral peak shows the bandwidth is narrower than 50KHz : the resolution bandwidth of the spectrum analyzer. Fig.3b is the spectrum observed by a slow sweep of 1 second. The frequency fluctuation observed is more than 1 MHz, though the instability is less than that of the specification of an ordinary magnetron for an electric oven.

The antenna aperture of the horn is 50cm(=D) by 50cm and the gain is 22dB. Since the altitude of the antenna is 2m(=D^2/λ :205cm) and the distance from the antenna to the ground is between the limits of near-field(=$D^2/(2\lambda)$) and far-field(=$2D^2/\lambda$), the beam footprint is nearly the same as the antenna aperture[1]. In this case the output power which makes the power density on the ground 23mW/cm^2 is about 100W.

Microwave safety guideline

Japanese microwave safety guideline, which is based on ANSI standard [2], shows the safety level of the microwave irradiation. The safety level is based on the specific absorption rate(SAR) which is determined from thermal effect on human bodies. The safety level of 2.45GHz is 1.6mW/cm^2(2.1dBm/cm^2) for the general public.

Besides, the Japanese regulation of the permissible radiowave from industrial equipment is considered for reference. The regulation level is 100μ V/m(-115dBm/cm^2) at the distance of 100m or at the end of the site area. This level is extremely low, since radiowave heaters, for example, can not actually satisfy the regulation.

Evaluation of shielding capability

(a) Shielding by metal meshed net

Shielding effect was measured in the condition of perpendicular incidence to the mesh plane as shown in Fig.4. The shielding factors of both large and small meshed nets were measured by comparing receiving powers with and without the shielding net. Microwave signal propagates directly from one antenna to the other without multipath, since the gain of two antennas is 26dB and the beamwidth is small about 10 degree. The result is listed in Table 1. The large meshed net for security has little effect of shielding because the mesh size is larger than a quarter of a wavelength. Small meshed net has reasonable shielding effect of near 30dB.

(b) Measurement of electromagnetic condition around ME facility

Microwave power density outside the shielding net was measured by a waveguide aperture at 1.8m from ground and a spectrum analyzer. Instead of measuring the electromagnetic(EM) condition at all the places, front and side leakage attenuation characteristics and directional pattern of microwave leakage were measured to evaluate the EM condition. They were measured with lower half and full shield covering along the progress of construction.

Attenuation characteristics of the front and side directions and directional patterns are shown in Fig.5-7, respectively. All the range attenuation characteristics agree with square-law attenuation curves. Since the height of the half shielding is the same as the altitude of the transmitter antenna, the leakage is large due to the direct propagation from the antenna. Therefore, the leakage level was reduced by about 20dB with full cover shielding. This reduction is also shown between the directional patterns in Fig.7. The main leakage beam appears in the pattern of half shielding, but it disappears in that of full shielding. The pattern of "8" character of full shielding shows that the residual leakage is composed of microwave energy after the reflection between the fences and diffraction over the fence. The directional pattern also shows the strongest direction agrees with the antenna axis. Therefore, the power density of the antenna front is important to evaluate the EM condition as shown in Fig.5. Power densities of three positions A-C were measured along the antenna axes. These positions are definitely shown in the map of Fig.1. The positions A and B are just before and after the woods. The power density at B is greatly reduced by the woods, though some fluctuation of the leakage power level was observed. The power density at C beyond a small bank is further reduced nearly to the low level of the Japanese regulation to industrial equipment.

The microwave leakage condition around the facility is satisfactorily good for safety on the basis of the Japanese microwave safety guidelines.

Conclusions

A microwave exposure facility for evaluation research of safety of microwave power transmission. In advance of the experiments of irradiation, the electromagnetic condition of the circumstance was measured and evaluated. From the results, the low leakage of microwave power from the facility is satisfactorily certified.

References

[1]A.W. Rudge, et al, "The Handbook of Antenna Design, Vol.1," Peter Peregrinus Ltd, 1982

[2]American National Standards Institute, "American National Standard Safety Levels with respect to Human Exposure to Radio Frequency Electromagnetic Field. 3KHz to 300GHz," ANSI C95 1-1991.

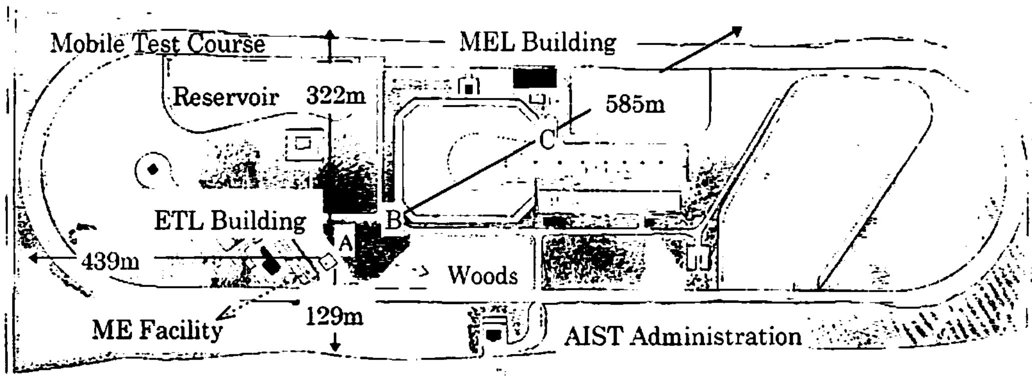

Fig.1 Microwave Exposure(ME) Facility in AIST Second Research Center

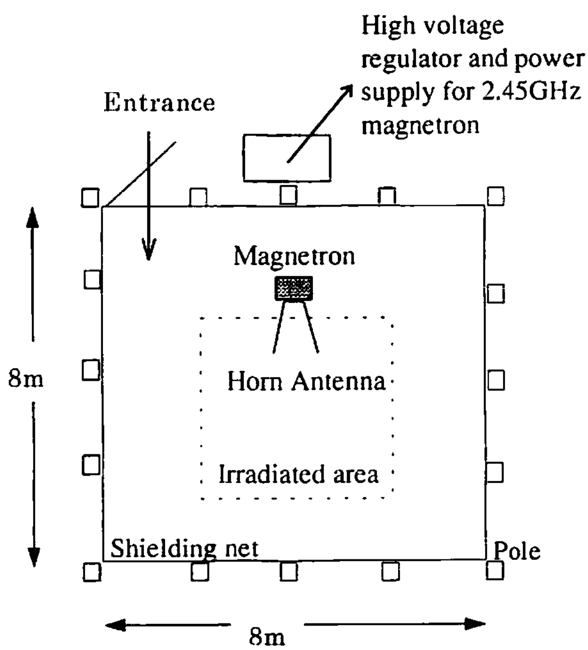

Fig.2 Structure of Microwave Exposure facility (Top view) . Fences are 2m high.

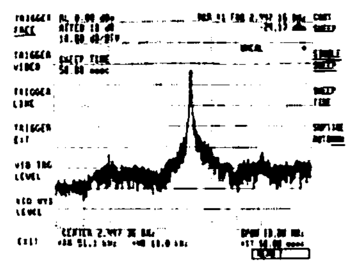

Fig.3a Instantaneous spectrum of magnetron output

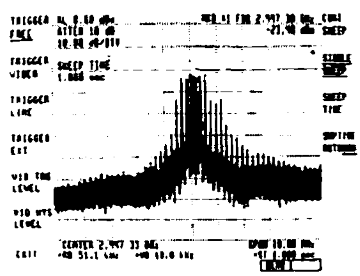

Fig.3b Frequency spectrum of magnetron measured during one second

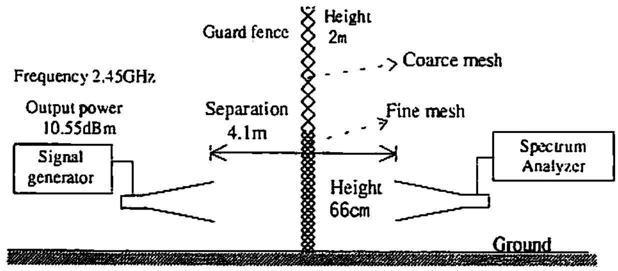

Fig.4 Measurement of Shielding effect by metal meshed fence

	Received Power dBm	Shielding factor
Free space	-13.74	
Large mesh	-16.15	2.41dB
Small mesh	-43.17	29.43dB

Table 1 Measurement of shielding capability of large and small meshes

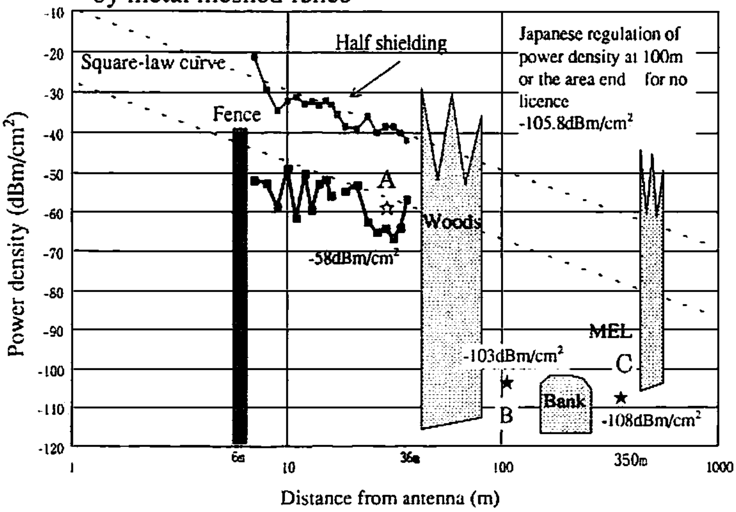

Fig.5 Power density of microwave leakage in the front direction of the antenna

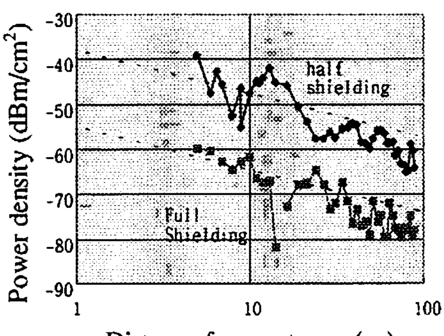

Fig.6 Power density of microwave leakage toward the side of the shield fence

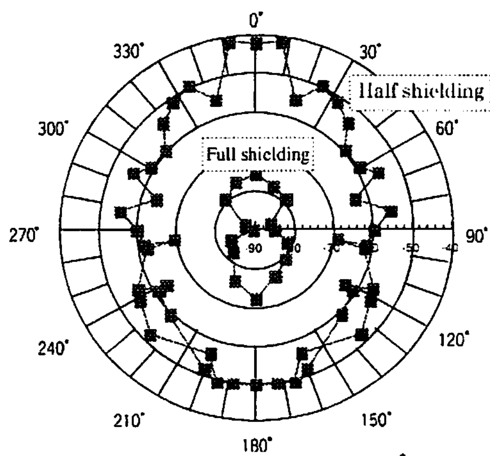

Fig.7 Directional pattern (dBm/cm²)of microwave leakage from ME facility with Full and half height shielding nets.(measured at 30m from antenna)