Non-Bethe's Theory and its Experimental Verification of Two Coupled Microwave Cavities

K. MINAMI and M. SUGITO[a]

Tokyo Denki University, Chiyoda-Ku, Tokyo, 101-8457 Japan
[a] National Institute for Fusion Science, 322-6 Oroshi-cho Toki 509-5292 Japan

kminami@msa.biglobe.ne.jp

Theory on two coupled microwave cavities different from that given by Bethe [1] is formulated and verified experimentally. Recent development of microwave communication including movable phones has changed human life significantly. Nevertheless, we do not necessarily understand basic electromagnetic field for communication among metal structure with a small hole or aperture, for example. In 1944, Bethe analyzed such problems in detail and elucidated how incomplete existed solutions were and how complicated corrected ones were. At the end of the paper, he discussed the field patterns in two coupled microwave cavities separated by a metal screen with a small circular hole. In the cavities, co-phase $(\phi = 0)$ and anti-phase $(\phi = \pm\pi)$ oscillations were distinguished, where ϕ is the phase difference. The fields in both sides of the hole in the former oscillate in phase, as if there is no effects of the screen at both sides of the hole and oscillate as a whole cavity, whereas in the latter the fields are 180 degree out of phase with each other, as if two cavities oscillate nearly independently.

In order to verify his theory experimentally, we try to detect microwave transmission through cylindrical coupled cavities for frequency range 2-4 GHz. Inner wall of the fabricated cavities is silver with inner radius 77 mm and length 160-200 mm changed by movable disks. Coupled cavities with Q factors on the order of 10^4 have an identical axis and separated by a copper circular disk with a hole of various sizes and locations. Two loop antennas are inserted in the radial direction. One of them is to feed microwave less than 50 mW with 0.4 % frequency modulation to excite TE or TM modes to the first cavity, and the other detects the transmission coefficient $|T|^2$ from the second cavity that is displayed on the digital oscilloscope TDS2024B (Tektronix) through 40 dB amplifier Model-APA0204 (ALC microwave Ltd). Somewhat surprisingly, no predicted modes by Bethe are observed until now. Instead, it has been found that the observed modes of resonance as a function of frequency are explained by an assumption of $\phi = \pm\pi/2$, namely, the coupling hole is a reactive (inductive or capacitive) element for microwaves propagating in positive and negative directions inside the cavities. The coupled cavities are successfully analyzed by using the scattering matrix theory for microwave circuits [2]. Our limited experiments do not invalidate the Bethe's theory.

[1] H. Bethe, Phys. Rev. Second Series **66**(1944)163.
[2] J. L. Altman, Microwave Circuits, New York: van Nostrand, p. 202(1964).