§13. Hybrid Mode Propagation in 62-m Corrugated Waveguide

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Experimental and theoretical studies on the transmission loss of hybrid mode HE_{11} in the circular corrugated waveguide indicate that the HE_{11} mode has negligible loss with a nearly linear polarization. We manufactured the aluminum corrugated waveguide with 88.9 mm in diameter and with about 70 m in length including 8 corners for the outdoor use between buildings for power transmission of millimeter waves with 53.2 GHz and 84 GHz. The period, width and depth of corrugation are 1.7, 1, 1.1 mm, respectively.

The signal source of 84 GHz switched-on and -off by a PIN diode with pulse width of 50 ns and repetitive rate of 3 kHz is injected through a circulator and a directional coupler. A dominant $TE_{10}^{\square}$ mode in the WR-10 waveguide is converted to a $TE_{11}^{\bigcirc}$ mode via transducer and passed through a smooth copper taper. At this point, the copper waveguide is connected to the HE_{11} mode converter with the diameter of 16.25 mm and then jointed to a diameter taper to a 88.9-mm output diameter which is followed by 62-m straight corrugated waveguide. The unit length of the waveguide is 100 cm and also as auxiliary waveguides 40 waveguides with 25 cm in length are also used. A metal plate is inserted between the joint flanges. By a sampling scope, millimeter waves are monitored via reflection port of directional coupler. When the reflected wavepacket arrives at the directional coupler, no forward wavepacket coexists. Also reflected wavepacket which passes the directional coupler is absorbed by a circulator. Since thus directivity of the directional coupler becomes complete in actual, waveform and group delay time can be measured exactly.

By plotting the group delay time t as a function of transmission distance x, it is found that the value of best-fitted group velocity is 2.93×10^8m/sec which is slightly less than the light velocity. The group velocities $v_{gm} = \beta_m c^2/\omega$ for the HE_{11}, HE_{21} (TE_{01} and TM_{02}) modes are 2.996×10^8 m/sec, 2.994×10^8 m/sec, respectively. The results agree well the observed group delay time within 2%.

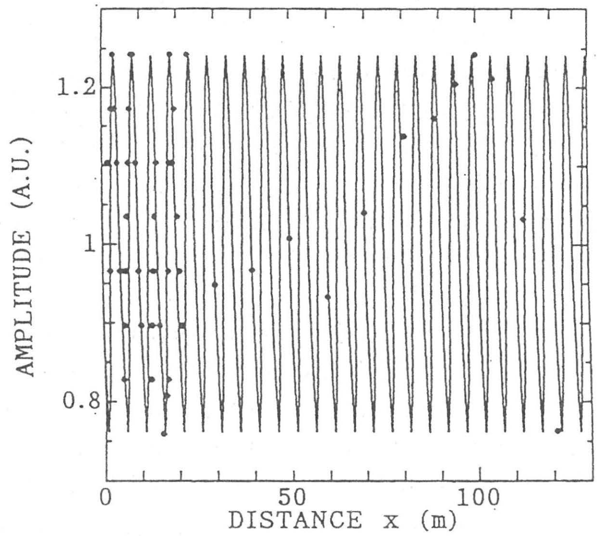

Fig. 1: Amplitudes of returned wavepacket vs. x

In Fig. 1, amplitude of wavepacket as a function of x is plotted by normalizing data with average value. If single mode would be transmitted in the waveguide, the plotted curve monotonically decreases and its slope gives loss. The oscillatory trace shows that other mode is strongly excited. To infer the attenuation constant, we could use the slope of centerline in envelope of oscillatory trace in Fig. 1. No obvious decrease in average value of measured trace is observed. We infer that the attenuation of HE_{11} mode is quite small such as 2 db/km which is the limit of measurements. Although the theoretical value is 9.43×10^{-2}db/km at $d = 1.23(\lambda/4)$, it is difficult to compare the experimental value with theoretical one. By least square method, we fit the experimental data to the function $1 + A_0\cos(\delta\beta x + \tau)$ where $A_0 = 0.24$ and $\delta\beta = 1.245$(rad/m), respectively. As in Fig. 1, $\delta\beta$ is nearly equal to the calculated $\Delta\beta = 1.280$ between the HE_{11} and HE_{21} (TE_{01} and TM_{02}) modes.