VII-2. DEVELOPMENT TOWARDS PRACTICAL APPLICATIONS OF TE_{01}-MODE CIRCULAR WAVEGUIDES, LEAKY WAVEGUIDES, AND BEAM WAVEGUIDES

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Recent developments on application of topical waveguides in Japan are reviewed. Continuous and concentrated efforts have been made to improve the TE_{01} circular waveguide system for materialization of millimeter wave communication. Another feature of our developments is the practical application of such up-dated microwave techniques as leaky waveguides and beam waveguides to the vehicular communication or train control systems.

TE_{01} Circular Waveguide. The Electrical Communication Laboratory of Nippon Telephone and Telegraph Corp. plans to make the field experiments on a 4.2 km tandem hybrid waveguide system composed of helix waveguides and lined waveguides in 1966. Under close contact with E.C.L., we have been developing the practical waveguides.

One of the main problems for practical helix waveguides was to provide large dissipation for unwanted modes with an economical structure. Many kinds of wall structures have been investigated. One solution was to apply carbonized acrylo-nitrile fiber for the lossy layer outside the helix. Figure 1 shows measured attenuation of the TE_{11} and TE_{12} modes in a helix waveguide of 51 mm inside diameter.

Copper-plated steel pipes with a polyethylene lining have been developed for the lined waveguide. Much effort has been made to obtain straight steel pipes and to increase durability of the guide. The relation between the statistical deviation from straightness and the increase of attenuation was investigated experimentally. Figure 2 shows a typical measured attenuation of the lined waveguides around 50 GHz. A one-trip pulse method was used instead of the shuttle pulse method to measure accurate attenuation of the waveguides. The additional attenuation due to imperfect straightness proved to be negligible. The manufacturing process has been improved to increase the peeling strength and the durability of the polyethylene lining.

An FM radar was developed to detect small imperfections of the waveguides installed for a long distance. Fine distance resolution is a main advantage of this technique in comparison with a pulse radar.

Leaky Waveguide. A combination of TE_{01} circular waveguides and leaky waveguides opens the prospect of a long-haul "wired wireless communication" in the centimeter and millimeter region. An interesting application is for large-capacity vehicular communication. The Railway Technical Research Institute of the Japanese National Railway suggested the application to railway communications which we have been investigating. A trunk line of circular waveguides transmits microwaves over a wide frequency band with low attenuation. Leaky waveguides installed along the route of the vehicles enables continuous coupling to be maintained with every vehicle.

Three types of leaky waveguides have been developed for this use:
1) the leaky grooved guide
2) the tandem hybrid line of metal and helix guide with radiation holes
3) the open-spiral helix waveguide.

The leaky grooved guide has slanted walls with radiation slots on both sides, as shown in Fig. 3. This guide is designed for use around 7 GHz. These leaky groove guides are coupled to the circular waveguide through directional couplers at intervals of about 80 meters. A travelling-wave antenna with an elliptic-cylindrical reflector has been developed for a moving vehicle in order to obtain efficient coupling. Careful consideration has been made to keep uniform coupling by gradually increasing the radiation to compensate for attenuation of the leaky waveguide.

The tandem hybrid line of metallic and helix waveguide with radiation holes is suitable for a very low loss leaky waveguide system. Fig. 4 shows the metallic waveguide structure, with spacing between the two lines of holes selected to give a desirable radiation pattern in the transverse plane. The spurious modes generated by the disturbance of radiation holes are absorbed by the helix waveguides intermittently inserted along the line.

The open spiral helix waveguide has been developed to minimize generation of spurious modes due to radiation. A copper tape is wound with an appropriate spacing on the inside wall of a plastic pipe. Radiation intensity can be controlled by the ratio of the spacing to the pitch. Broadside radiation can be obtained when the pitch is selected near the guide wavelength of the guide. Fig. 5 shows an experiment on the coupling between these waveguides, which are designed to obtain a near end coupling.

Beam Waveguide. Beam waveguides have been originally proposed and investigated for light or sub-millimeter wave transmission. However, because of its low attenuation and open structure, it could be useful for special purposes in the microwave region. We have been developing beam waveguides for vehicular communication uses described above. Reflector-type phase transformers are preferable to dielectric lenses; two types have been investigated. The first is composed of two parallel concave reflectors, as shown in Fig. 6. Waves are propagated reflecting between the reflectors as in a conventional waveguide, and are converged into a beam by the transversely concave structure. The field distribution and transmission characteristics have been analyzed and measured experimentally. One of the remarkable features of this system is its belt-shaped field distribution, which suggests its use for an obstacle detection system for high-speed railways. Experiments have been made to verify this performance.

The other beam waveguide configuration investigated is composed of two kinds of reflectors, vertical concave and horizontal concave. These reflectors are disposed separately in two lines and the waves are propagated reflecting alternately between them. This shape of reflector is preferable to the usual three-dimensional concave from the practical point of view. Since the delay distortion of the transmitted signal due to spurious modes is much less for this system than for the parallel concave reflector system, it may be most effectively applied to a communication medium for a long distributed service area such as railways and highways.

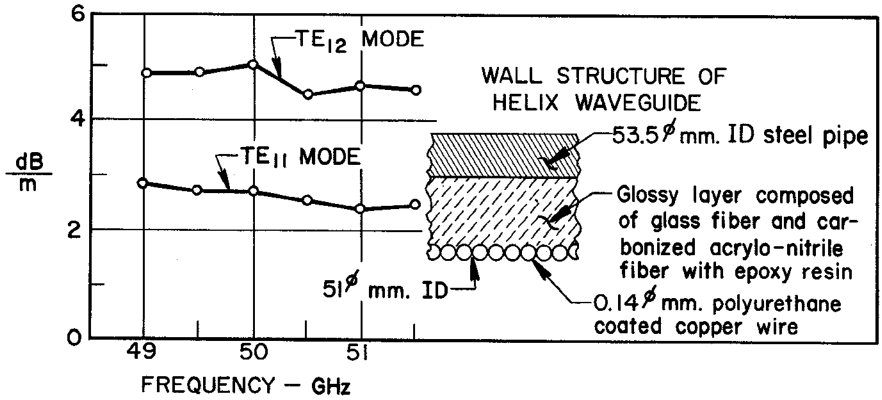

Figure 1. Attenuation Constants of Unwanted Modes of Helix Waveguide

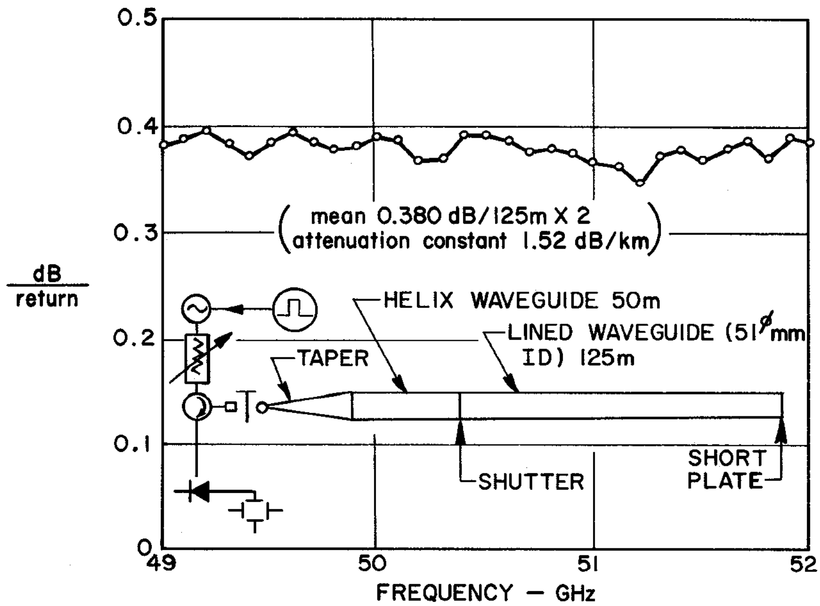

Figure 2. Attenuation of TE_{01} Mode in Polyethylene-Lined Waveguide

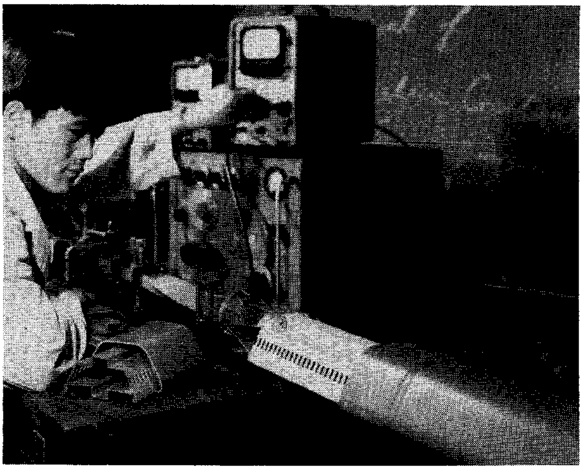

Fig. 3. Leaky grooved guide with radiation holes on the side walls and a plastic cover.

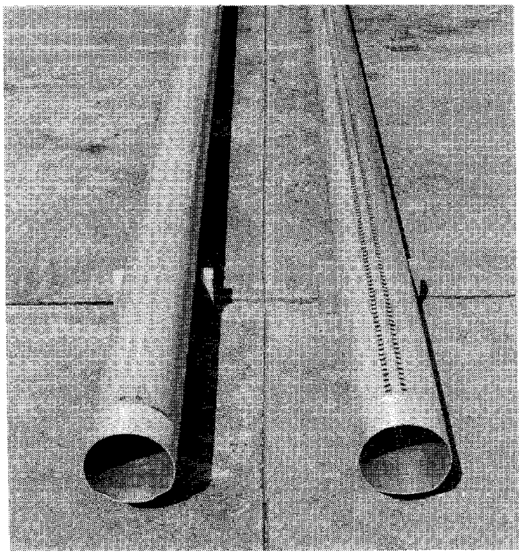

Fig. 4. Leaky circular waveguide with radiation holes.

Fig. 5. Leaky open-spiral circular waveguide with parabolic reflectors for obstacle detection performance test.

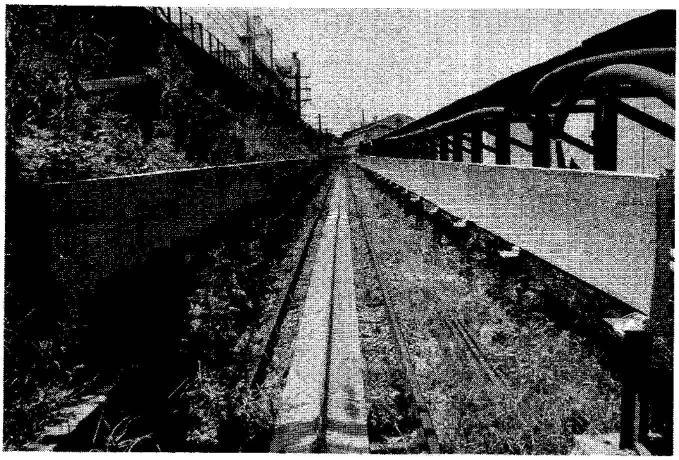

Fig. 6. Beam waveguide with parallel concave reflectors.