MONDAY, MAY 15, 1961
SESSION 1: MILLIMETER WAVES

10:45 AM - 12 NOON
CHAIRMAN: R. O. STONE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D. C.

1.1 QUASI-OPTICAL, SURFACE-WAVEGUIDE, AND OTHER COMPONENTS FOR THE 100 to 300 KMC REGION

F. Sobel and J. C. Wiltse
Research Division, Electronic Communications, Inc.,
Timonium, Maryland

Analytical and experimental studies were carried out to assess the value of various components and techniques in the frequency range from 100 to 300 kmc. The basic instrumentation consisted of adaptations of conventional rectangular waveguide devices, and signal power was provided by crystal harmonic generators driven with a few tens of milliwatts at a fundamental frequency of either 35 or 70 kmc. When silicon crystals are employed with video detection, output signal levels have a dynamic range of about 45 db above noise at 105, 140, and 210 kmc and somewhat less at 280 kmc. In an effort to obtain improvement, experiments are underway with gallium arsenide and other crystals.

Some optical devices which have remained essentially laboratory curiosities have analogues which can be used as practical system components in the millimeter wavelength spectrum. One such device, the phase-corrected Fresnel zone plate, was investigated in detail. An extensive analysis of this image-forming component was carried out and zone plates 20 cm. in diameter were constructed for use at 140 kmc and 210 kmc. These plates, which have focusing properties equivalent to lenses of speed f/1 (Fig. 1), were used to transmit millimeter waves over path lengths as great as 340 feet. A plot of attenuation versus distance for the 210 kmc system is shown in Fig. 2. Angular radiation patterns (H-plane) of the 140 kmc zone plate, used with a 15 db horn, were measured in both the Fresnel and Fraunhofer regions. The results obtained agree very well with theoretical calculations: the 3 db beamwidth in the far field was 42' and at a distance of 12 feet (one-fifth the Rayleigh distance) the beamwidth was 49'.

Smaller zone plates 7 cm. in diameter were incorporated in a Michelson interferometer which was operated at 140, 210 and 280 kmc. This system was used to determine the dielectric constants of a number of plastic and ceramic materials at 140 and 210 kmc, and some measurements of loss tangents were also made (Fig. 3). A method of frequency filtering by focal isolation was demonstrated with this equipment. Undesired harmonic frequencies are defocused and screened out of the system by the use of simple aperture stops. This technique should prove useful at the shorter millimeter and submillimeter wavelengths, where waveguide cutoff filters are extremely difficult to fabricate and have very high losses.

The disadvantages of hollow metal waveguide (high attenuation of dominant-mode rectangular waveguide and high construction cost of TE_{01}-mode circular waveguide) prompted an investigation of surface waveguides for transmission of energy in the 100 to 300 kmc region. Attenuation was measured and compared against calculated values (Fig. 4) for various dielectric image lines for frequencies as high as 150 kmc. It was found that the attenuation is lower (for a given area of dielectric cross section) when the dielectric is in the form of a thin tape (rectangular or elliptical in cross section) rather than the usual semicircular shape. The loss per unit length for the tape line can conveniently be adjusted to be nearly an order of magnitude lower than for rectangular waveguide. A theoretical analysis shows that single-mode (HE_{11}) propagation occurs over a wider frequency range with the tape line than with the line having a semicircular dielectric cross section.

An analysis was made of TM_{01} wave propagation at millimeter wavelengths on a transmission line consisting of a cylindrical coated or uncoated conductor. (Modes other than the TM_{01} are highly attenuated and are not significant except near the launcher.) The low loss and reasonable field extent of the cylindrical-conductor transmission line offer an advantage over dominant-mode rectangular waveguide, in which the attenuation may be two orders of magnitude greater (Fig. 4). Furthermore, the power handling ability is much greater for the single-conductor lines than for rectangular waveguide. Wide ranges of attenuation and field extent are available from various combinations of wire size, material, and/or dielectric coating. Experimental wire transmission lines of several different diameters were built and used to measure attenuation. Special launching horns were designed and constructed to generate the TM_{01}-mode (Fig. 5). The measured attenuation for the wire lines was much lower than that for dominant-mode rectangular waveguide but higher than the theoretical value for smooth straight wires. The increased loss is attributed to surface irregularities and small bends in the wire.[1]

---

[1]The research reported in this paper has been sponsored by the Electronics Research Directorate of the Air Force Cambridge Research Laboratory, Air Research and Development Command, under Contract AF 19(604)-5475.

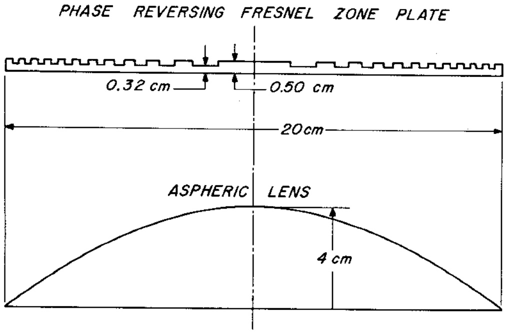

Figure 1 - Zone Plate and Equivalent f/1 Lens for 140 kmc.

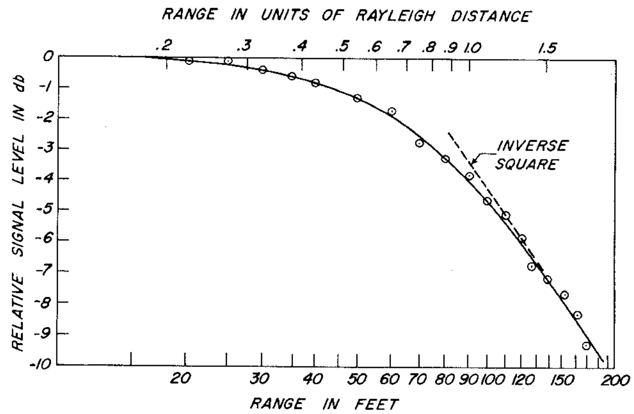

Figure 2 - Optical Transmission of 1.4 mm Waves Over Extended Paths.

DIELECTRIC PROPERTIES OF SEVERAL MATERIALS			
MATERIAL	DIELECTRIC CONSTANTS		LOSS TANGENTS
	140 kMc	210 kMc	140 kMc
POLYSTYRENE	2.52± .01	2.53± .01	.002
REXOLITE	2.47± .01	2.50± .06	.002
TEFLON	2.05± .01	2.08± .03	.003
LUCITE	2.56± .10	2.58± .10	---
MYLAR	3.35	------	.01
ETHYLCELLULOSE	3.71	------	.1

Figure 3 - Electric Properties of Several Materials

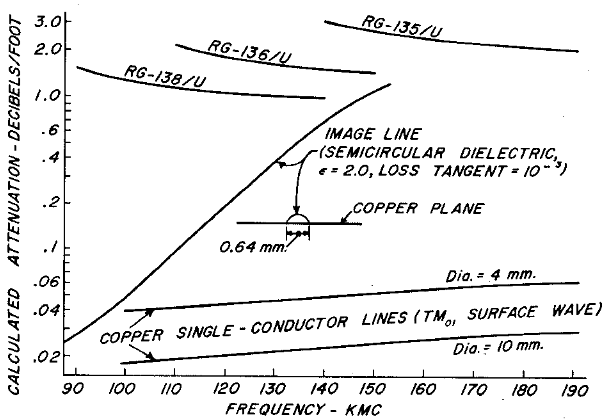

Figure 4 - Attenuation for Rectangular Waveguide (TM_{10}), Image Line (HE_{11}), and Single Wire Line (TM_{01}).

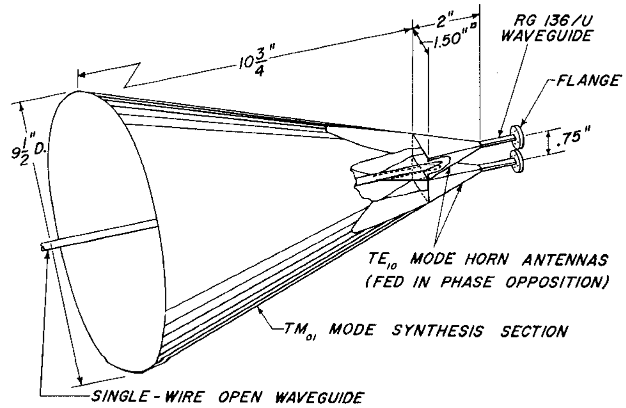

Figure 5 - TM_{01} - Mode Launcher for Single-Wire Line.