GENERAL SAFETY PRECAUTIONS
MICROWAVE RADIATION
WAVEGUIDE HOT PATCHING AND RADIATION PROTECTIVE GARMENT

CONTENTS **PAGE**

1. GENERAL

1.01 Hot patching of microwave waveguides refers to the technique of transferring waveguides (carrying RF energy) from one location to another in a short interval of time, or to the insertion of a new section of waveguide into working waveguide runs, usually ***without loss of service.*** The need for such action usually comes about from the need to rapidly restore service due to the loss of an antenna or to replace waveguide sections or networks in the course of normal maintenance, system modifications, or rearrangements. In all such cases, the period during which the energized waveguide is capable of radiating into space is relatively short, generally in the order of a few seconds.

1.02 The purpose of this section is to describe the potentially hazardous volume of space adjacent to an open-ended energized waveguide and to describe safe procedures to be followed when making hot waveguide patches. Microwave radiation exposures to personnel making hot-patch waveguide rearrangements are somewhat different from the radiation exposures encountered by personnel in the electromagnetic fields produced by omnidirectional antennas or by swept-beam directional antennas associated with radars. These differences are time of exposure, partial body exposure, and the limited volume of significant power density. The volume of potentially hazardous power density in the hot-patch case is relatively small and exists with fixed relationship to the opened energized waveguide. A good understanding of these general boundaries of the radiation volume enable one to take precautions that will permit safe working procedures.

1.03 The ***power density*** produced by a radiating source (commoniy expressed in milliwatts per square centimeter) is directly proportional to the power radiated and is inversely proportional to the square of the distance from the radiating antenna aperture. Determination of the distance from the open waveguide necessary to reach a safe working level is developed in the paragraphs that follow.

1.04 The hazards of radiation to human beings has been the subject of considerable research and investigation. As a result of this broad effort, safe or tolerable levels of radiation to which the human body may be safely exposed have been established. There are two types of radiation generated by radio transmitters that significantly affect the human body: ionizing radiation and microwave radiation. Both of these types of radiation are discussed in Section 010-150-001. ***Ionizing radiation is not a factor*** in the generation of low-power (such as power utilized by terrestrial point-to-point microwave systems) electromagnetic energy at microwave frequencies. Microwave (nonionizing) radiation is the type of radiation under discussion in this section. The major effects of microwave radiation on the human body are thermal, i.e., heat producing.

1.05 In general, the thermal effect of microwave radiation on human tissue depends upon three factors: the power density of the RF field causing the exposure, the length of time of the exposure, and the temperature-humidity conditions of the environment.

2. PROPAGATION FROM AN OPEN-ENDED WAVEGUIDE

2.01 The radiation emerging from an open energized waveguide is propagated from the open end of the waveguide along the projected axis of the waveguide. Because of the flanges on the waveguide and the properties of microwave propagation through the waveguide, very little energy is refracted backward from the waveguide flange. Thus, only the area adjacent to and forward of the open end of the waveguide connected to the active transmitter will present an area of potential hazard. Most of the high-density energy leaving the waveguide will be contained in a semispherical volume of space elongated somewhat along the projected axis of the waveguide and whose base would lie approximately on a plane created by extending the waveguide flange. Figure 1 is a pictorial representation of the energy emitted from an open-ended waveguide.

2.02 Figures 2 and 3 are measured patterns of radiation directivity. The directivity patterns were obtained by rotating a test receiver antenna about an open-ended 4- and 6-GHz energized round waveguide and plotting points of equal field density. As predicted by theoretical calculations, the radiation pattern shows more directivity for the 6-GHz energy than for the 4-GHz energy. Clearly, as shown by Fig. 2 and 3, the area of potential hazard from an energized open-ended waveguide is in the volume of space beyond the flange and centered on the projected axis of the waveguide.

2.03 In addition to the elongated sphere of RF energy just described, significant increases in power outside this elongated spherical volume are possible from reflections. Reflections, caused by fairly large metal surfaces in proximity to the open waveguide, also make measurements of power density difficult and somewhat unreliable in the area of influence of these reflected fields. However, the short time periods (a few seconds) of exposure expected in these hot-patch procedures greatly

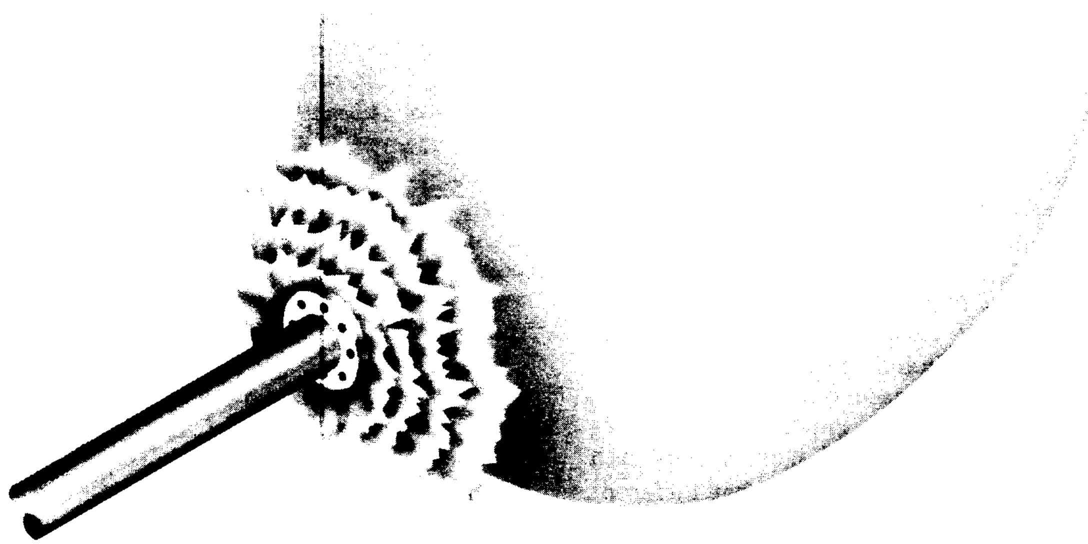

Fig. 1—Electromagnetic Energy Emitted from an Energized Open Round Waveguide

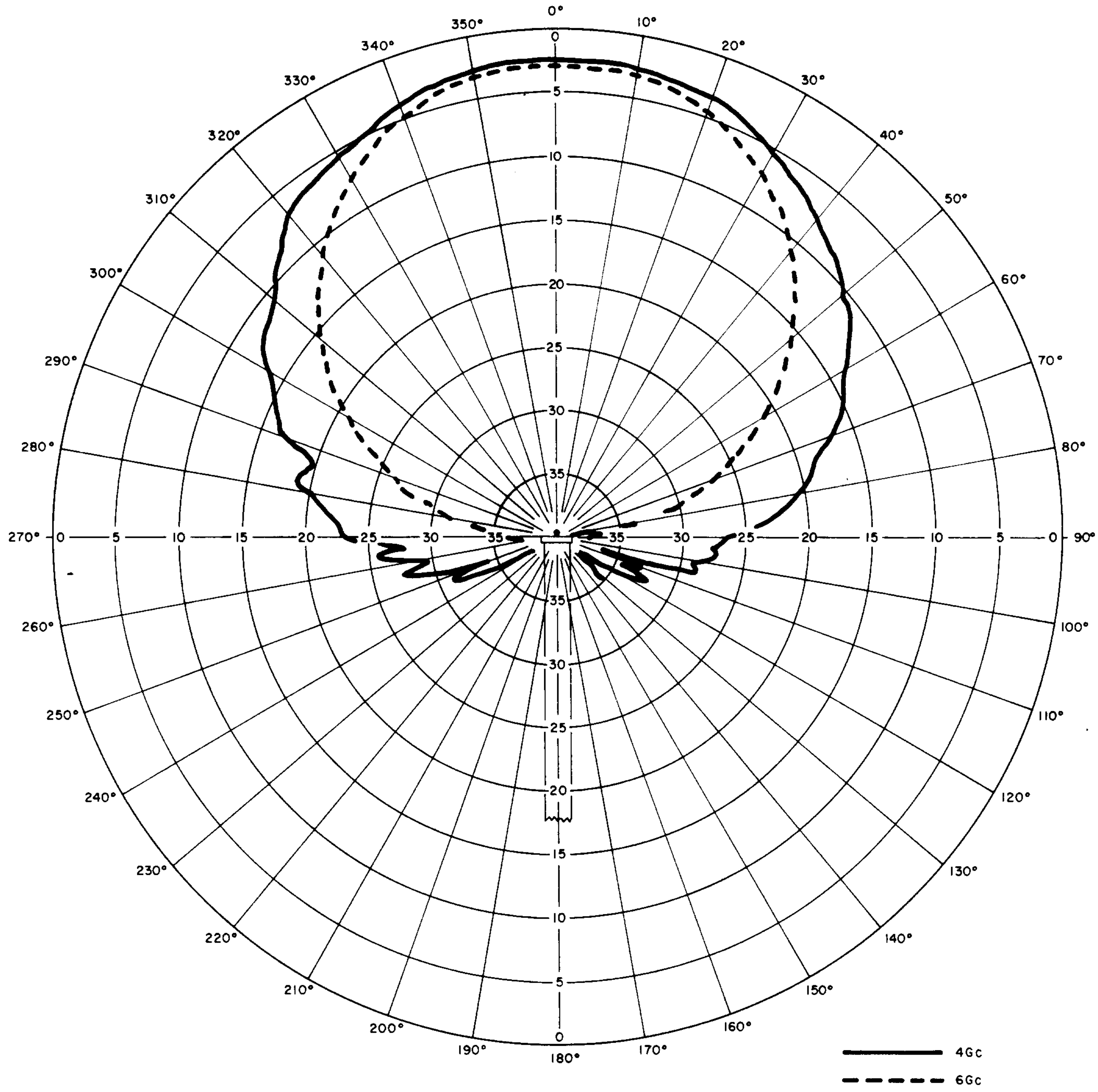

Fig. 2—Vertical Polarization Round Guide, H Plane

minimize the potential hazard of such possible increases in power density.

3. SAFE LIMITS FOR MICROWAVE RADIATION

3.01 The Bell System has adopted microwave radiation limits based on average power density of the nonionizing radio fields (see Section 010-150-001). These limits are as follows:

Radiation Protection Guide—Radiation level which should not be exceeded without careful consideration of the reasons for doing so.

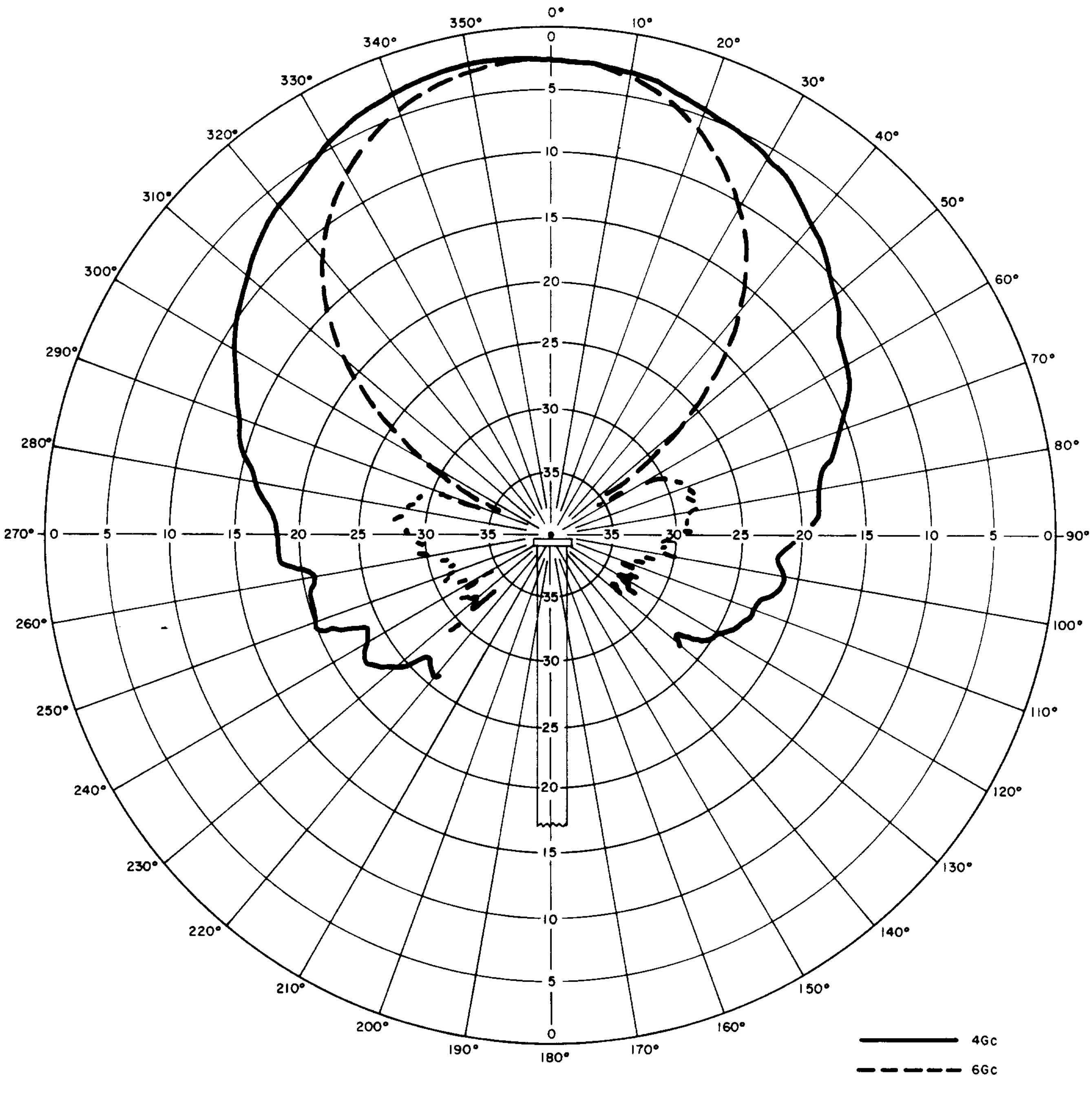

Fig. 3—Horizontal Polarization Round Guide, E Plane

Recommendations—For normal environmental conditions and for electromagnetic energy of frequencies from 10 MHz to 100 GHz, the radiation protection guide is 10 mw/cm^2 (milliwatt per square centimeter) as averaged over any possible 0.1-hour period. This means the following:

Power Density: 10 mw/cm^2 for periods of 0.1 hour or more.

Energy Density: 1 mwh/cm^2 (milliwatthour per square centimeter) during any 0.1-hour period.

3.02 The calculations of waveguide power that will permit safe working conditions are based on an exposure limit of 10 mw/cm^2 and a normal environment as defined in Section 010-150-001, i.e., a temperature-humidity index (T.H.I.) of 70 or less. It is recommended that in cases of abnormal environment (a T.H.I. of more than 70) personnel performing the hot patching should wear the Bell System microwave protection suit described in Section 010-150-001.

3.03 The power density of the electromagnetic field existing adjacent to an open-ended energized waveguide is dependent upon the transmitted power in the waveguide, the directivity pattern (gain) of the waveguide aperture, and the distance from the waveguide aperture.

3.04 Practical considerations, such as human arm lengths, the requirement to work from ladders, and the requirement to use hand tools to open or close waveguide flanges, limit the distance that can be maintained from an open energized waveguide during the hot-patch operations to approximately 12 inches. Based on these considerations and the 10-mw/cm^2 power density limit for microwave exposures to personnel, it is possible to calculate the maximum power in the waveguide that can be safely hot patched without protective clothing. Using the 12-inch separation and applying the 10-mw/cm^2 limit, calculation shows that up to 30 watts of RF power in waveguide may be safely hot patched. Measurements have verified these calculations. This 12-inch separation is safe for all cases except directly on axis for round waveguides. For this special case, to care for aperture directivity, the safe working distance should be 24 inches. In any case where a working distance of 12 inches cannot be maintained with up to 30 watts of power in the waveguide, protective clothing should be worn.

3.05 In general, it is not practical to attempt to work on a waveguide flange at a distance of more than 12 inches from the body, head, and eyes. ***Therefore, it is recommended that no hot patches of waveguides containing more than 30 watts of RF power should be performed without the use of protective clothing.*** Microwave power in excess of 30 watts results from the combination of TD-2, TH, and/or TD-3 transmitters and/or TDA-1 power amplifiers feeding common waveguide runs.

4. CALCULATION OF WAVEGUIDE POWER

4.01 The power in the waveguide is a function of the type(s) and number(s) of transmitters feeding the waveguide run. In this situation it is not necessary to consider waveguide and filter losses (minor factors) within the waveguide run. The power in the waveguide may be determined by ***adding together the power of the individual microwave transmitters feeding the waveguide.*** Table A lists the rated power output of all types of microwave transmitters expected to be encountered in present day telephone plant.

5. SPECIAL CIRCUMSTANCES

5.01 For hot patches where the 30-watt exposure limit is exceeded and protective clothing is not available, it may be possible to reduce temporarily or turn off the power of one or more of the transmitters to satisfy the 30-watt requirement. ***Such procedures should be referred via line of organization.***

6. REFERENCE

6.01 The following reference may be of interest to those who wish to study this subject in greater detail:

Bell Telephone System Monograph 3865—Some Technical Aspects of Microwave Radiation Hazards.

TABLE A

POWER RATINGS OF VARIOUS MICROWAVE SYSTEMS IN CURRENT USE

MANUFACTURER	SYSTEM	RF POWER OUTPUT (WATTS/CHANNEL)
Western Electric	TJ TL TL-2	0.5 0.5 0.5
	TM TD-2 TD-3	0.5 2.0 5.0
	TH TD-A1 TM-A1	12.5 5.0 2.0
Lenkurt	75A — 6 GHz 76A — 6 GHz 76D — 11 GHz 74B — 6 GHz 71F — 2 GHz	10.0 1.0 1.0 1.0 1.0
RCA	CW 60 & CW 60 volts — 6 GHz	0.1
General Electric	TRS 660 — 6 GHz	1.0
Kellogg — ITT	K 260 — 2 GHz	1.0
Motorola	MR 20 — 6 GHz MV 30 — 6 GHz	0.1 1.9
Farion	PT 2000 — 2 GHz SS 2000 — 2 GHz	5.0 1.0
Budelman	14 CN (141 CN) (2 GHz)	1.5
Raytheon	KTR II — 6 GHz KTR III — 6 GHz KTR IVA — 4 GHz	2.5 20.0 0.7
Collins	MW 109 B3 (Mod. 1) — 6 GHz MW 109 A3 — 6 GHz MW 109E — 6 GHz	20.0 20.0 20.0
	MW 609E — 11 GHz MW 609 A3 — B3 — 11 GHz MW 109 B4 — 6 GHz	10.0 10.0 20.0
	MW 609 B4 — 11 GHz MW 108D — 6 GHz MW 608D — 11 GHz	10.0 1.0 1.0