X-Band Uplink Microwave Components

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Waveguide components for use in the 400-kW X-band radar system will be electrically stressed to a considerably greater extent than previously experienced in DSIF equipment. The electrical characteristics of several possible waveguide sizes have been investigated. A size has been selected which offers an adequate safety margin for the X-band radar and other possible X-band uplink applications.

I. Introduction

The design goal established for the uplink portion of the X-band radar equipment includes transmitting a nominal 400-kW signal at 8.495 GHz. Economic considerations have resulted in a design which utilizes two 250-kW klystron amplifiers whose outputs are combined into a single port. The X-band uplink program includes the development of microwave components such as a power combiner, waveguide switches, and a variety of waveguide transmission line assemblies which must operate satisfactorily at 400-kW levels.

II. Design Considerations

The theoretical power-handling capability of a waveguide system operating under ideal conditions is a function of the waveguide geometry and the operating frequency. The waveguide selected should have as large a cross-section as practical. However, it is of paramount importance to select a waveguide size which will support only the fundamental mode throughout the anticipated range of operating frequencies. Figure 1 indicates the ratio of operating frequency to the fundamental cutoff frequency as a function of frequency for a number of commercial standard waveguide sizes. The frequency range of interest indicated in Fig. 1 covers the anticipated requirements for the DSIF (7.1 to 8.5 GHz).

The choice of WR-137 is unacceptable because of its proximity to the TE_{02}-mode region at the 8.495-GHz radar frequency. The WR-112 and WR-90 sizes are acceptable from mode considerations but have significantly reduced power-handling capability. A new waveguide size, shown in Fig. 1, designated as WR-125 approximates the power-handling and attenuation performance of WR-137 but is not subject to the higher-mode problems. The internal dimensions of the WR-125 waveguide are chosen to have an exact 2:1 ratio. This characteristic will permit a much simpler scaling of the waveguide hybrid developed for the 400-kW S-band diplexer for use in the X-band radar power combiner.

The choice of waveguide geometry and frequency determines the theoretical power-handling capability. However, several derating factors must be taken into account in an actual, field operating environment. Some significant factors are listed in Table 1 with maximum values anticipated in the X-band radar design. It is noted that the net derating factor is 0.28. A comparison of the power capability of the various waveguide sizes is given in Table 2. The theoretical power calculations are based on a maximum electric field of 30,000 V/cm under ideal conditions.

The selected waveguide size should also afford a low value of attenuation. This characteristic is of importance with high-power operation in maximizing the radiated power and minimizing the heat load on the waveguide cooling system. Low attenuation is also desirable throughout the receiving waveguide system in order to minimize the receiver effective system noise temperature. The attenuation of the various waveguide sizes is presented as a function of frequency in Fig. 2.

III. Conclusions

The data presented in the above tables and figures indicate that the WR-125 waveguide size is acceptable for use with the X-band radar system, and for other possible DSIF X-band applications. The next higher-mode cutoff frequency is well above the X-band radar frequency. The power capability is 50% higher and the attenuation is 27% lower than that for WR-112. The planned 400-kW level represents 16% of the theoretical maximum of the WR-125 waveguide.

A review of DSIF high-power experience indicates that the X-band clock synchronization transmitter has produced the largest electrical stress on a DSIF waveguide system to date. This transmitter operates at 7.15 GHz, with up to 150 kW into both WR-112 and WR-137 waveguide assemblies. In the WR-112 components, this operating power is 10% of the theoretical maximum. The safety margin for the X-band radar appears to be adequate using the WR-125 waveguide.

Table 1. Power derating factors

Parameter	Value	Derating factor
Electric field factor	Power combiner assumed to be worst component	0.70
Altitude	900 m above sea level	0.80
Maximum VSWR	1.10	0.90
Internal waveguide temperature	55°C	0.80
Dust particles, metal chips, moisture	—	0.70
Overall derating		0.28

Table 2. Waveguide power capability

Waveguide	Theoretical maximum power, MW		Derated maximum power,[a] MW	
	7.1 GHz	8.5 GHz	7.1 GHz	8.5 GHz
WR-90	0.53	0.88	0.15	0.25
WR-112	1.44	1.69	0.40	0.47
WR-125	2.25	2.50	0.63	0.70
WR-137	2.61	2.83	0.73	0.79

[a]Derating 0.28.

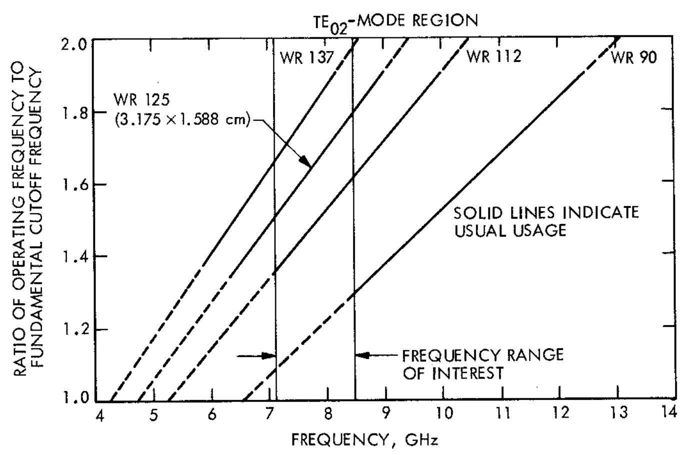

Fig. 1. Waveguide mode considerations

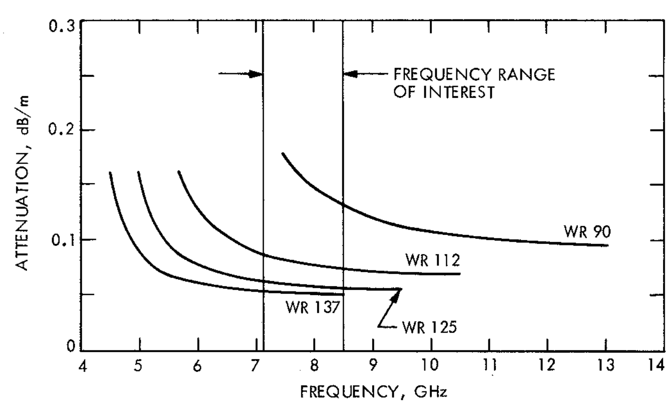

Fig. 2. Attenuation versus frequency