A DUAL-CHANNEL ROTARY JOINT FOR HIGH AVERAGE POWER OPERATION

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Introduction - Recently an X-band, dual-channel rotary joint was needed for the airborne terminal of a satellite communication link.[1] Low losses were necessary in the high average power transmit channel (12.5 KW, CW) to avoid excessive temperature rise, and in the receive channel to reduce the noise temperature of the system. Other important considerations were: no liquid or forced-air cooling; restricted size limitations; low cross-coupling between channels.

A new type of rotary joint combining the TM_{01} mode and the circularly-polarized TE_{11} mode in circular waveguide was developed which satisfied the electrical, thermal, and size requirements of the system.

Description - One-half of the rotary joint contains a multi-mode exciter and a polarizer section (Fig. 1). The TM_{01} exciter for the transmit channel consists of a right-angle junction between a circular waveguide (a) and a rectangular waveguide (b) with common coupling provided by two slots (c). These two slots are symmetrically located relative to the center-line of the rectangular waveguide so that the slot currents are equal in magnitude and are flowing in opposite directions. Hence, the dominant mode excitation in the circular waveguide is suppressed and the next two higher modes (TM_{01} and TE_{21}) will be excited. Since the TE_{21} mode is below cutoff in the chosen size of circular waveguide, propagation can take place with only the TM_{01} mode having the circular symmetry needed for rotary joint operation. The far end of the rectangular waveguide is terminated in a short circuit which is adjusted in position for best impedance match. Irises and capacitive elements employed in the various sections for vernier impedance matching are not shown here to simplify the illustration.

The TE_{11} exciter for the receive channel consists of a right-angle junction between a rectangular waveguide (d) and the circular waveguide. The mode excitation in the circular waveguide is aligned parallel to the slots (c); therefore, there can be no cross-coupling between the transmit and receive ports. The interface in the circular waveguide at the receive junction is made in the form of three parallel slots instead of a single rectangular aperture to offer less impedance discontinuity to the TM_{01} mode propagation. Identical slots (e) cut in the circular waveguide directly opposite to the receive input port excite a shorted waveguide section (f), functioning as an additional matching element for the TE_{11} mode.

The linearly-polarized TE_{11} mode in the circular waveguide is converted by a polarizer section to a circularly-polarized wave which also has the circular symmetry required for rotary joint operation. This polarizer is a conventional type made of two metallic ridges (g) positioned on opposite sides of the circular waveguide and lying in a plane oriented at 45° with respect to the input wave. A waveguide analog technique[2] was employed to determine the circular waveguide diameter and the ridge dimensions for an optimum compromise between the desired and undesired modes of propagation. In the chosen geometry, these ridges present only a very small impedance discontinuity to the TM_{01} mode propagation and do not cause cross-coupling between the transmit and receive channels.

Another longitudinal slot (h) is cut along the center-line of the bottom wall of the transmit input line in one of the rotary joint exciters. This slot feeds a short section of rectangular waveguide leading to an absorbing resistor. Theoretically, this third-channel port does not couple to the TM_{01} mode but does absorb any circularly-polarized TE_{11} mode rotating in the opposite sense to that of the receive mode. Absorbing this small reflected wave caused by minor impedance mismatches reduces the WOW, or signal output variation with rotary joint rotation, of the receive channel operation and improves the receive input VSWR.

The other half of the rotary joint is identical to Fig. 1 except that the absorbing port is omitted. A photograph of the engineering model of the complete dual-channel rotary joint constructed for X-band is shown in Fig. 2.

Circular-waveguide continuity at the interface between the rotating and non-rotating halves of the rotary joint is provided by non-contacting, quarter-wave choke sections.

Experimental Measurements - The measured VSWR characteristics with matched terminations at the outputs of the two channels (plotted in Fig. 3) basically met the design goal of 1.2:1 or less over both bands. The receive data shows the characteristic VSWR variation inherently associated with the use of a mode having linear phase variation with angular rotation and impedance discontinuities at both ends of the rotary joint.

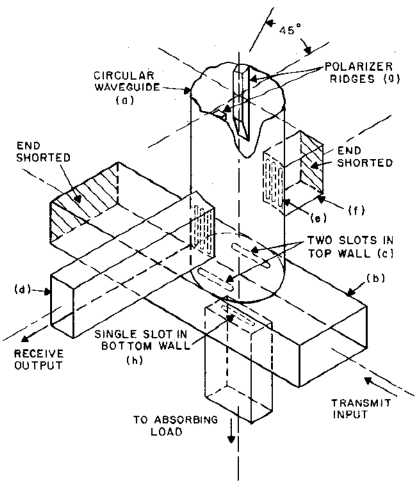
The isolation between channels was 35 db or greater over both transmit and receive bands measured at their respective ports. The isolation between the receive port and the absorbing load was at least 18 db, and that between the transmit port and the absorbing load was greater than 25 db. This means that only an insignificant portion of the receive energy is wasted in the absorbing load and that a 50-watt load resistor is sufficient to absorb the power transferred from the 12.5 KW transmit channel.

The WOW was found to be less than 0.05 db over the transmit band and from 0.1 to 0.2 db over the receive band. The r.f. losses as measured on a test model were 0.1 db or less over the transmit band and from 0.1 to 0.2 db maximum over the receive band. The same transmit loss was correlated at a single frequency from thermal tests made during a 10-KW power test of the rotary joint.

REFERENCES

(1) This work was carried out under contract No. F33615-69-C-1601 from the Air Force Avionics Laboratory, Wright Patterson AFB, Dayton, Ohio.

(2) "A Distributed Electrical Analog for Waveguides of Arbitrary Cross Section", P. R. Clement and W. C. Johnson, Proc. I.R.E., January 1955, p. 89.



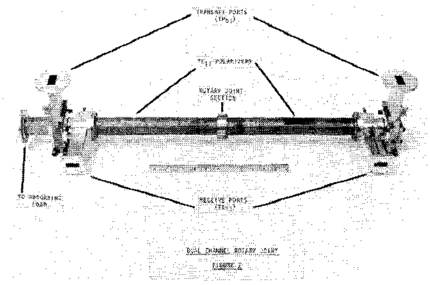


FIG. 1 - MULTI-MODE EXCITER AND POLARIZER

FIG. 2 - DUAL-CHANNEL ROTARY JOINT

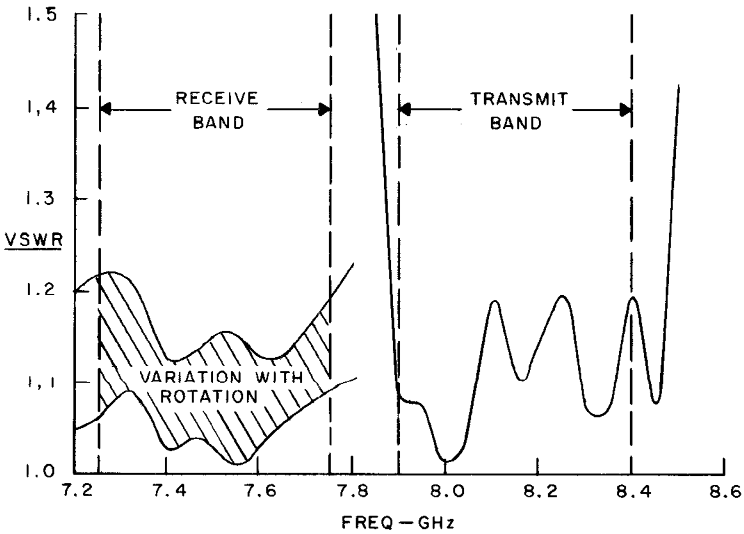


FIG. 3 - VSWR VS FREQUENCY