A HIGH POWER ROTARY WAVEGUIDE JOINT

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A new radio frequency rotary joint with high-power capability which lends itself to stacking for multichannel service has been developed. Many present designs are either limited in power handling capability, or are plagued with electrical resonance, and higher order waveguide mode problems.

This rotary joint is essentially a waveguide mode converter. The rectangular waveguide feed, TE_{10} mode, is converted to a circular TE_{01} mode for transmission across the rotating interface, and then reconverts to the rectangular TE_{10} mode for output.

The conversion makes use of the fact that the electric and magnetic fields of a rectangular guide transmitting in the TE_{10} mode are very similar to a segment of the circular TE_{01} mode. A series of binomial power splitters divides the rectangular feed TE_{10} waveguide into sixteen parallel rectangular waveguide sections having TE_{10} fields of equal amplitude and phase. The cross section of these sixteen waveguides then changes slightly by flaring the H dimension of the guide to form a keystone segment. The sixteen segments are arranged circularly. The traverse electrical fields close on themselves, and the magnetic fields are radial. The circular mode is approximated since the flaring of the transitions do not change the waveguide fields, and the larger dimension of the keystone is less than $\lambda_{c/2}$, thus preventing the occurrence of higher modes.

Septa which taper to knife edges at the interface of the joint are placed on the edges formed by the adjacent keystone sections. The knife edge prevents disturbance to the fields at the interface of the joint when it is rotating. The segments are maintained in phase by making equal path length for each segment through the feed arrangement. These conditions must exist at the interface or overall field distortions will result in losses.

This waveguide configuration differs from the normal circular TE_{01} waveguide in that a center hole now exists, through which waveguide feeds from other identical joint sections mounted axially may pass, thereby providing possibility of multichannel stackups.

The circular mode generated then propagates across a small gap to an identical rotating section and reconverts in inverse sequence to a single rectangular TE_{10} output. No RF leakage occurs at the gap because the electric fields close on themselves in the circular TE_{01} mode existing at the transition.

A "C" band feasibility model was built utilizing axial stacking of "Y" power splitters to feed the sixteen keystone transitions. Twists of different angles were used for alignment of the splitters. This arrangement, though bulky, insured excellent phase relationship between the individual segments of the circular interface. In this model a gap of 0.005" was maintained at the interface. Results of tests on this model were excellent. The input VSWR indicated no resonances occurred over a 10% bandwidth. The input VSWR did not change while rotating the joint. The attenuation throughout the entire rotary joint was only 0.01 to 0.07 db higher than that of a straight section of waveguide the same wave length as the test model. After pressurizing the input and output splitters, the model handled in excess of three megawatts over the 10% bandwidth with no breakdown. There was no breakdown upon rotation at this power level. No RF leakage was detected at the interfaces at a -60 db level.

A compact, folded design was developed to make the joint more usable. The feed system is a series of waveguide "T" power splitters arranged circularly in a plane orthogonal to the rectangular end of the transitions. Each component of this feed system has been matched out in "C" band, and the maximum VSWR of any individual component is 1.05 over a 20% bandwidth. Several components tested 1.01 or 1.02 over the same bandwidth. The transformers were tested at the maximum available power of 1.4 megawatts without breakdown. The input VSWR for this arrangement was calculated to be 1.3 over a 10% bandwidth.

The design requirement for this rotary joint was a maximum VSWR of 1.15 over a 10% bandwidth. The large number of components in the feed system make it difficult to achieve this requirement. Therefore a portion of the VSWR is cancelled by the following procedure. The input is offset from the center of the feed arrangement by one quarter-wave length. A one-quarter-wave length section is added below the fourth splitters on the side of the feed system opposite the offset. This configuration is used in both the stationary and the rotating halves of the joint. Thus, between these two quarter-wave sections a minimum of 78% of the VSWR is cancelled over the 10% bandwidth. Although the losses are higher, they are still small as the values being cancelled are small.

The maximum input VSWR now becomes the value of the input splitters plus 22% of the value of the components between the quarter-wave steps times two because the input VSWR is the sum of the stationary and rotating sections. As the keystone transitions have practically no VSWR, they do not add to the value obtained. With this arrangement the input VSWR is within the design requirements of a maximum of 1.15.

The principal features of this rotary joint design are as follows. The power handling capability is in excess of that of the main waveguide itself. As the power level in each element at the interface is one-sixteenth of the input, the joint does not have to be pressurized. The large hole through the center permits two or more rotating antennas to be independently fed from a corresponding number of fixed transmitters which may operate on different frequencies with different or variable power outputs. The joint is free from electrical resonances and from higher order waveguide modes. There are no ripple effects or commutation in input impedance characteristics with rotation. All sliding or other electrical contacts are eliminated. There is no radiation leakage because of the uniform 360° closed field. It is amenable to very broad band operation. The field pattern is similar to the field pattern associated with the TE_{01} mode in a circular waveguide but with the advantage that higher order modes cannot propagate in this structure. The system can also be used as a power adder by adding the outputs of several synchronized klystrons. This would enable the use of available klystrons to obtain high-power levels.

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