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Demountable K/Q Band Coaxial Feed for Cassegrain Antenna

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***Abstract*—In this paper demountable K/Q bands feed for satellite communication Cassegrain antenna is reported. The feed is based on the combined coaxial-circular waveguide, in which outer wall of a circular waveguide is used as an inner conductor of a coaxial waveguide. This design allows to simultaneously transmit and receive signals in two widely separated frequency bands. A coaxial joint, which is the key part of the feed, is proposed and described in details. The joint performs several functions. First is to transmit the microwave energy through both waveguides. Second is ensuring the waveguides sealing. And third is ensuring the circular and coaxial waveguides alignment. The joint simulation results demonstrated return loss below –20 dB and insertion loss less than 0.06 dB in 20-21 GHz frequency range (K-band) as well as return loss below –30 dB and insertion loss less than 0.15 dB in 43-45.5 GHz frequency range (Q-band). Mechanical prototype of the joint was manufactured and tested.**

Keywords—coaxial waveguides, coaxial joint, reflector antenna feeds, dual-band feeds, multiband antennas, satellite communication

I. Introduction

Cassegrain antennas are widely used in satellite communications. The advantages of such antennas include small longitudinal dimensions and a possibility of placing the transmit/receive equipment behind the main reflector. If transmit to receive frequency ratio of an antenna is lower than 2, for example, if antenna works only in Ku (11/14 GHz) or only in Ka (20/30 GHz) satellite frequency bands, then its feed can be made based on a circular waveguide. In cases when an antenna operates for transmit and receive in two widely separated frequency bands and the frequency ratio is more than 2, for example in K/Q bands (20/44 GHz), its feed is usually made using coaxial design, since in this case it is difficult to provide single-mode propagation of the fundamental TE_{11} mode when using a single circular waveguide. In this design, originally proposed by Lee in [1], upper frequency band (e.g. 44 GHz) signal propagates along a circular waveguide, the outer surface of which is simultaneously used as a central conductor of a coaxial waveguide for lower frequency band (i.e. 20 GHz) signal. Wherein, both the inner circular and the outer coaxial waveguides operate at the TE_{11} waveguide mode. We refer such a waveguide as a combined coaxial-circular waveguide. A coaxial design for a reflector antenna feeds now is widely used in various radio systems, e.g. in 5G [2], radio astronomy [3-4] and especially in satellite communications [5-8].

For transportable satellite communication stations with large dimensions of a main reflector, the reflector can have a disassembleable design. In this case, the feed can be demountable for a convenience of a station transportation (Fig. 1). In this design, the front part of the feed with a subreflector can be separated from the rear part of the feed, fixed on the main reflector and connected to the transmit/receive equipment. For antennas operating with transmit to receive frequency ratio of less than 2, when the feed is built using a circular waveguide, it is easy to provide a demountable feed design. For antennas operating with transmit to receive frequency ratio of more than 2, in which coaxial design is used, it is difficult to use a demountable feed, since it is necessary to simultaneously connect or disconnect two waveguides - an internal circular and an external coaxial.

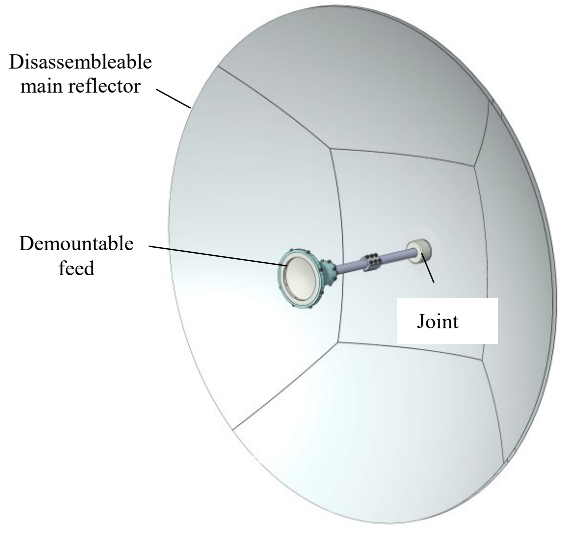

Fig. 1. Disassembleable Cassegrain antenna with demountable feed.

This paper describes the design of a demountable K/Q band Cassegrain antenna feed based on the combined coaxial-circular waveguide. The key part of the demountable coaxial feed is a coaxial joint, which allows to mount or demount front part of the feed. In addition to ensure the transmission of a microwave energy through the joint, the proposed design also ensures the sealing of the waveguide's flanges and the alignment of inner circular and the outer coaxial waveguides.

II. Coaxial Joint Design

Proposed feed is shown in cross section in Fig. 2. It consists of two parts: the front demountable part and the rear fixed part, mounted to the main reflector. The front part includes a subreflector mounted on a hollow dielectric support, K-band axially corrugated horn, Q-band dielectric cone antenna, K-band matching circuits and K-band groove polarizer. Using corrugated horn for K band and dielectric cone antenna for Q band provides almost independent tuning of beamwidth in both ranges. Dielectric support is made from polyamide and have 1 mm wall thickness.

The rear fixed part of the feed includes the input and output rectangular waveguides, matching sections, orthomode transducers and a Q-band groove polarizer. Abovementioned microwave devices are well-known from the literature [9-11] and did not described in this paper.

The front demountable part of the feed is mechanically connected to the rear fixed part using a large diameter union nut. Proposed coaxial joint is used to connect two parts electrically. This original joint will be described in details. Joint design is shown on the inset of Fig. 2. It performs several functions. First of all, the transmission of the microwave energy through the both waveguides. Secondly, ensuring the waveguides sealing. And thirdly, ensuring the circular and coaxial waveguides alignment.

Following considerations were taken into account for the joint design. An obvious solution is when both the outer and inner tubes of the combined waveguide are connected mechanically by the ends. However, from a mechanical point of view, it is difficult to ensure reliable contact of the both tubes during multiple assembly and disassembly of the joint. Instead, in the proposed design, only the outer tube flanges are in straight contact, while the inner tubes do not have mechanical contact. Waveguides ends are covered with special axisymmetric dielectric bushings, which completely cover the waveguides ends when the feed is demounted. When the feed is mounted, bushings are pressed close to each other with flat parts, as shown in Fig. 2. A small gap s remains between the ends of the inner circular waveguides in this case, filled with the dielectric of the bushings. This gap insignificantly affects the propagation of the waves along the internal circular waveguide because the current on the walls of a circular waveguide with TE_{11} mode flows mainly in the transversal direction. Moreover, a dielectric resonator with a total length l_2 formed by both bushings in the inner waveguide has a frequency of the second oscillation mode equal to the central frequency of the feed Q band range. The electric field minimum at the second oscillation mode is located at the cylinder center, making the wave less sensitive to the gap. Also, additional matching cylinders of length l_3 have been added to expand the operating frequency band.

In the K-band coaxial path, this type of connection results in a break in the center conductor, which is equivalent to a series capacitance in the transmission line, because the current on the surface of the central conductor of a coaxial waveguide with TE_{11} mode flows mainly in the longitudinal direction. To compensate an existence of the capacitance the coaxial line outer conductor diameter enlargement of height h is applied, which is equivalent to adding a series inductance.

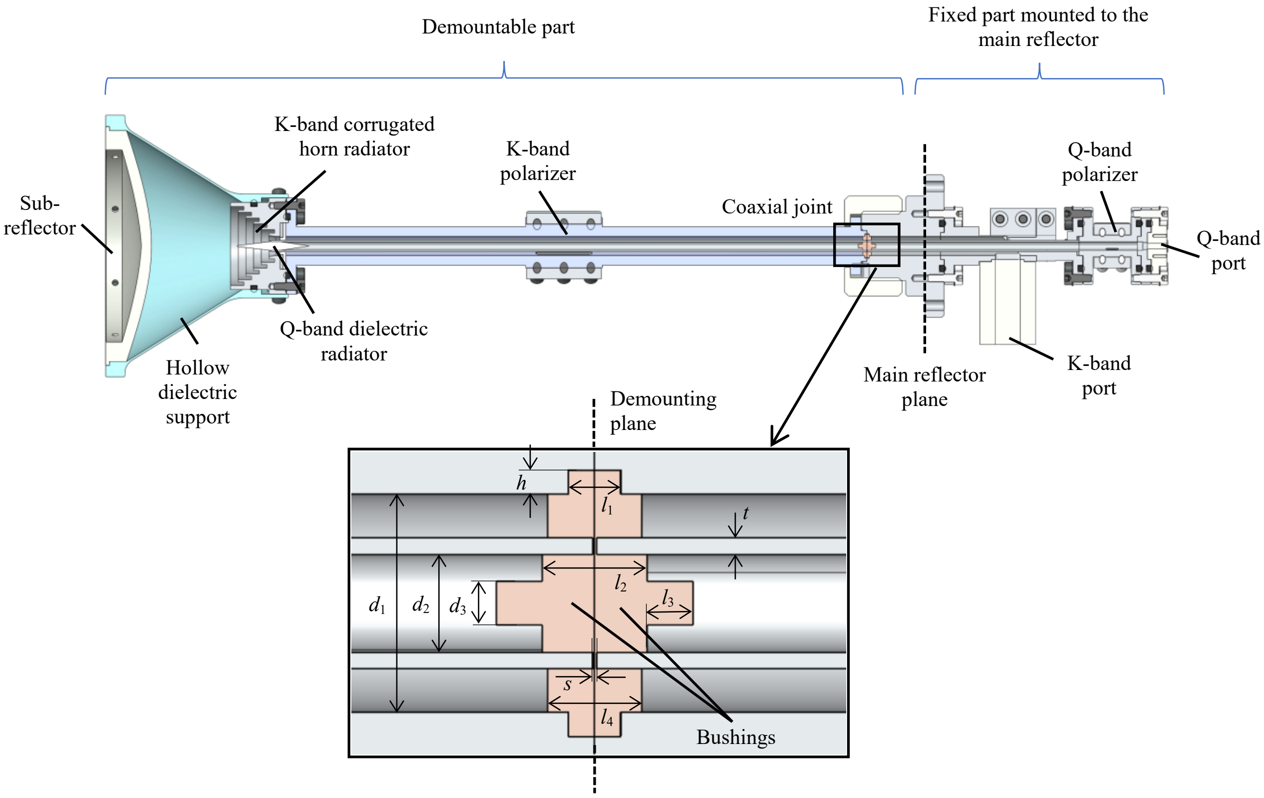

Fig. 2. Demountable coaxial feed cross-section. Coaxial joint is shown in details.

The oscillation circuit combined of the series capacitance and inductance, tuned to the central frequency of an operating band, provides the required high level of the transmission coefficient.

It should be noted that due to the presence of the gap in the inner waveguide, part of the energy from the inner circular waveguide penetrates into the outer coaxial one at Q-band frequencies. For small gaps, this fraction of energy can be rather small. Energy from outer coaxial waveguide at K-band frequencies do not penetrate to the inner circular waveguide due to the cutoff.

III. Simulation and Experimental Results

To confirm the proposed coaxial joint concept, it was designed and numerically simulated for frequencies from 20 to 21 GHz (≈4.9%) in the K-band, for which an outer coaxial waveguide was used, and frequencies from 43 to 45.5 GHz (≈5.7%) in the Q-band, for which an inner circular waveguide was used. PTFE was used as the bushing material (ε_r=2.1, tgδ=0.0002). Simulation of the device was performed using Frequency Domain Solver in CST Microwave Studio. Dimensions of the joint after tuning to the abovementioned frequencies are shown in Table I (see notation in Fig. 2).

Fig. 3 shows the coaxial joint simulated S-parameters in two operating frequency bands. Ports 1 and 2 was placed at the ends of the outer coaxial waveguide, and ports 3 and 4 was placed at the ends of the inner circular waveguide. Both waveguides were excited by TE_{11} mode. According to these results, in the frequency range from 20 to 21 GHz the joint has a return loss (S_{11}) less than −20 dB and insertion loss (S_{21}) no more than 0.06 dB. In the frequency range from 43 to 45.5 GHz, the return loss (S_{33}) is less than −30 dB and insertion loss (S_{34}) no more than 0.15 dB. Coupling between the K and Q-bands waveguides (S_{31}) in the Q-band is less than –22 dB, and in the K-band the coupling is negligable due to the cutoff in the circular waveguide.

It should be noted, that K/Q frequency band recently was engaged to provide additional satellite communication lines capacity. Herewith, typical satellite communication channel bandwidth is a few hundred MHz. Thus, the simulation shows that the proposed coaxial joint ensures the transmission of signals in both waveguides in a sufficient for satellite communications frequency range.

The K/Q band coaxial joint prototype was manufactured to check a mechanical property of this design (Fig. 4). PTFE bushings surface was chemically activated and it was glued to the aluminum tubes. It was confirmed that device provides sealing of the waveguide's junction and the proper alignment of the inner circular and the outer coaxial waveguides. The whole feed with the proposed joint will be manufactured as a next step of this work.

TABLE I. K/Q Band Coaxial Joint Dimensions

Parameter	Value (mm)	Parameter	Value (mm)
d_1	10	l_3	2.1
d_2	4.5	l_4	4.8
d_3	2	h	1.1
l_1	2.4	t	0.75
l_2	4.8	s	0.2

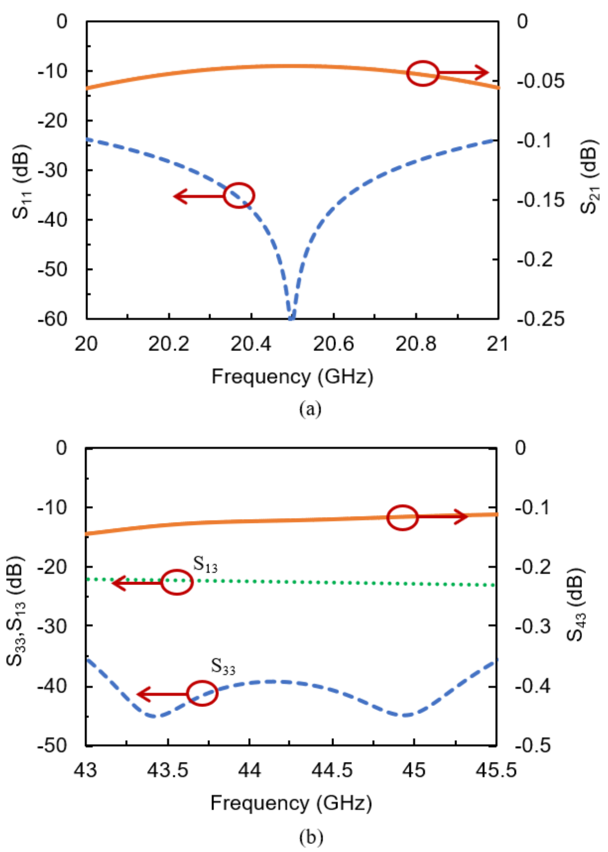

Fig. 3. Simulated characteristics of the proposed coaxial joint in K (a) and Q (b) bands.

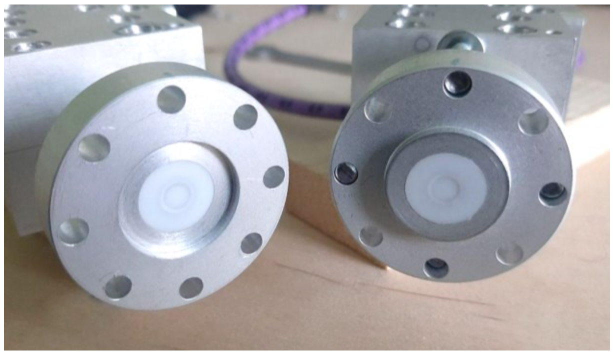

Fig. 4. Manufactured K/Q band coaxial joint prototype.

IV. Conclusion

As it is shown, demountable K/Q band coaxial feed for Cassegrain antenna could be realized using proposed joint design. Simulation results show that the joint provides low level of return losses, low insertion losses, and has an operating frequency band of about 5% for both circular and coaxial combined waveguides. This bandwidth is sufficient for satellite communications. Mechanical prototype tests show that it also provides significant mechanical properties – multiple assembly-disassembly of the combined coaxial-circular waveguide, its sealing, as well as providing the inner and outer waveguides alignment. Proposed design could also be applied in other frequency band feeds that use combined coaxial-circular waveguides, such as C/Ku or Ku/Ka feeds.

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