Compact K/Ka 4-Port Feed Subsystem for Dual Circular Polarisation

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***Abstract*— A compact four-port dual circular polarization feed antenna system for satellite communication is described. It consists of a septum Polarizer and two identical duplexers formed by an E-plane T-junction and of two iris filters, along with two electric field rotators since the vectors of the electric field in the rectangular ports must be vertical. This 4-ports system transmits and receives radio frequency signals in double track in which the transmission Tx is made through two ports having as access the standard rectangular waveguide WR42 and the reception RX is made also through two ports having as access the standard rectangular waveguide WR28. To separate the two ways at the circular common port (or rather at the antenna level) RHCP and LHCP was used.**

I. Introduction

Antennas for earth stations of satellite communication systems may be used to receive a signal from a satellite and may also be used to transmit a signal to a satellite by associating appropriate receiver and transmitter units with a feed horn of the antenna. The capacity of the earth station can also be increased by simultaneously transmitting and receiving two pairs of signals on the same transmit and the same receive frequencies if the two pairs of transmit and receive signals are polarized, because the two pairs of frequencies can be separated accordingly to the sense of polarization of each pair. Generally, the feed system is composed of the three distinct parts: the orthomode transducer (OMT), the polarizer and the antenna feeder. The OMT is a key component in orthogonal dual-polarized antenna feed systems, being used to separate Tx and Rx linearly polarized signals at the common port. The polarizer is a differential phase shifter that provide required (usually 90 degree) phase shift between two orthogonal linear polarizations in square or circular waveguide. In a matching condition these three elements are independent of each other and can be designed independently. In satellite communications systems, the transmission capacity can be increased doubling both ways of communication being based on the polarization of the signals. Systems that fulfil this operation are known as four port devices [1] - [2]. A 4 - port device allow the transmission and the reception of the signals to a space station of a satellite communication system.

In particular it consists of a waveguide technology system that generates two orthogonal polarization pairs in both transmission and reception bands. The dual frequency operation provides the communication users the opportunity to obtain dual-path operation with a single antenna. The dual-path operation can be used to double the capacity and can be relied on as dual-path redundancy to permit continued operation of at least one path in the event of failure of a component in the second path.

The conventional OMT [1] - [2] often serves like a basic network of feeding that provides two linear polarizations for the radio transmitter (TX) and the receiving one (RX) in the satellite communications. A broadband polarizer, which is always connected in the common port of the OMT, is necessary to establish a circular polarization system if the TX and the RX use different frequencies. For satellite communications systems, this can pose problems due to the wide separation of the RX and TX frequencies and due to the bulky of the whole subsystem [1]. Several alternatives have been proposed [2] - [5] to obtain the dual band dual circular polarization feed antennas. However, the complexities of these feed networks increase the cost and make the mechanical tolerance effectiveness. The purpose of our alternative is to present a small size K/Ka band 4-port feed network that works in both, sufficiently separated, frequency bands 20-21.4GHz and 29.8-31.5GHz. This 4-port feed network architecture is well-suited for separated dual band applications with good performances and good manufacturability mechanical tolerances. A prototype of the 4-port device was designed, manufactured and tested. It has been fabricated using conventional milling techniques. An internal view of the device that fulfils these requirements is shown in the fig 1.

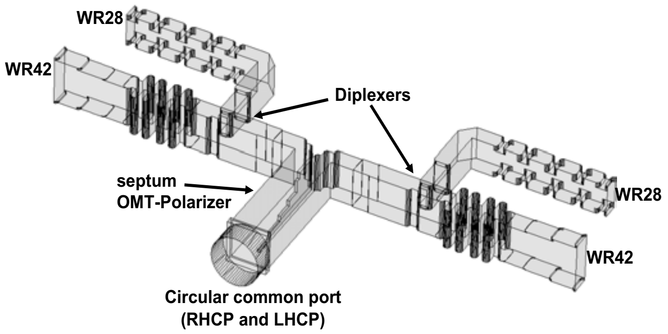

Fig. 1. 3D internal view of the K/Ka dual band dual circular polarization 4-ports feed subsystem network.

II. DESIGN AND TEST

The 4-ports subsystem is formed by a septum OMT-polarizer, two duplexers, and two 90º field rotators. It is a satellite communications feed system network that works in two frequency bands supporting dual circular polarizations. The lower frequency band (Tx: 20-21.4GHz) allows the transmission of two signals, one with right hand circular polarization (RHCP) and the other one with left hand circular polarization (LHCP). Similarly, the higher frequency band (Rx: 29.8-31.5GHz) receives two signals with orthogonal circular polarization. Thus this dual circular polarization 4-ports system, allow to double the quantity of information to transmit or to receive. This 4-ports system can also work in two port operation by terminating the non used ports in matched load.

A. Septum OMT-polarizer

The septum polarizer is well-known device, widely employed in satellite antennas, which combine in a single element the functions of orthomode transducer and polarizer, thus reducing volume and weight. A given signal coming from a rectangular port is split into two 3dB orthogonal signals at the common port with a time delay of 90º between them [6]-[8]. This produces a circular polarized signal: a RHCP associated to one of the rectangular ports and a LHCP associated to the second rectangular port. We have designed a compact solution for a dual band OMT polarizer that avoids the use of additional iris loaded corrugated sections [9]. The proposed device is based on a conventional septum polarizer in waveguide technology covering two separate bands, were an extension of its normal (rather narrow) frequency band of operation has been achieved to meet restringing specifications for the 20/30GHz satellite link communication bands. The septum polarizer consists of three physical ports: two of them in rectangular waveguide (WR34) and another common port in circular or square waveguide. This compact design exhibits good return losses (>30dB) at the rectangular and circular ports as well as high isolation (>40dB) between polarizations. Furthermore, axial ratio is kept as low as 0.4dB in both communication bands. Fig.2 presents a fabricated prototype for the septum OMT-Polarizer along with the obtained result in the simulation.

Fig.3 shows the comparison between the measured and simulated results.

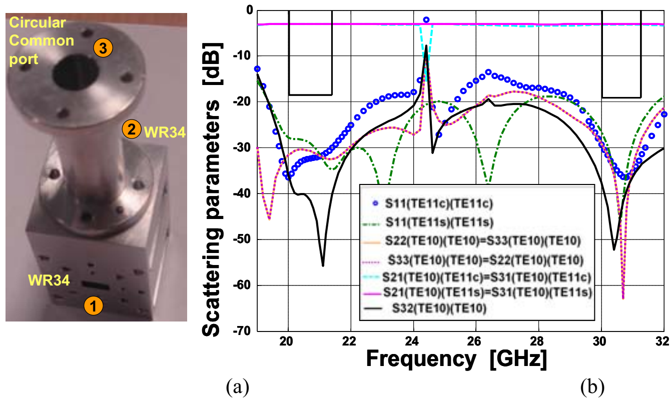

Fig.2. Septum OMT-Polarizer. a) Fabricated prototype. b) Simulated results of the scattering parameter magnitudes

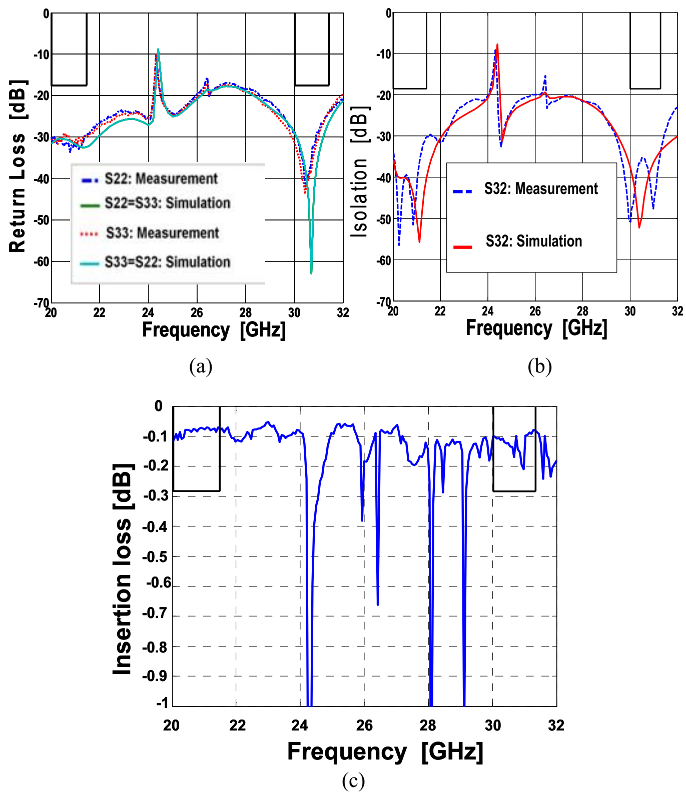

Fig.3. Comparison of the results of the OMT-Polarizer. a) Reflection coefficient at the rectangular ports. b) Isolation between rectangular ports. c) Insertion losses.

As it can be seen in the following graphs (fig.2 and fig.3), there is a good agreement between the results of measurement and the provided by simulations. The return losses are better than 30dB in both frequency bands, the insertion losses are about 0.1dB in the Tx band and about 0.2dB in the Rx band, the isolation is better than 40dB in the Tx band and of 35dB in the Rx band. We have also controlled the isolation between fundamental modes and higher order modes. We have found that the worst case isolation is better than 70dB in the entire frequency band (20-31.5GHz) including therefore the two frequency bands of interest.

B. Diplexers

We have designed and manufactured two identical diplexers that essentially consist of an E-plane T-junction followed by two iris filters: one channel filter is in K-band and the other is in Ka-band. A standard waveguide WR34 must be used for the common port of the diplexer so that is compatible with the input port of the septum OMT-polarizer. Moreover, we have used the standard rectangular waveguide WR42 in lower band port (Tx) and WR28 in the higher band port (Rx). The relative frequency bandwidth of the whole diplexer is about 43%. The two channel filters have relative frequency bandwidths of 7% and 6.5%, respectively. A waveguide E-plane bifurcation junction with a scattering element must be selected first to satisfy the wideband common port matching.

The Fig.4 shows the experimental measurements of the reflection and transmission coefficients for both frequency bands, as well as the isolation. As it can be seen in the previous graph there is a good concordance between the simulated results using µWizard-Mician and those obtained by experimental results. The measured return loss at the port 1 (Tx) is > 40dB while at the port 2 (Rx) is better than 30dB. Insertion losses of the diplexer in both the Tx and Rx bands is about 0.1dB, and the isolation between the two rectangular output ports is about 120dB.

C. 90º degree electric field rotator

To interchange the field alignment at the OMT level we use two 90º electrical field rotators [11]. It consists of a simple intermediate section that allows changing the sense of the electrical field 90 degree with respect to its initial alignment. Comparisons between simulated an experimental results are shown in Fig.5 along with a view of the fabricated prototype.

III. MEASUREMENT RESULTS FOR THE 4-PORT SUBSYSTEM

For the measurement of the entire subsystem, we have used a standard TRL calibration in WR34 waveguide because it covers both frequency bands of interest. Since the accesses of the rectangular ports are in standard waveguides WR42 and WR28, we have designed low loss transitions from WR34 to WR42 and from WR34 to WR28.

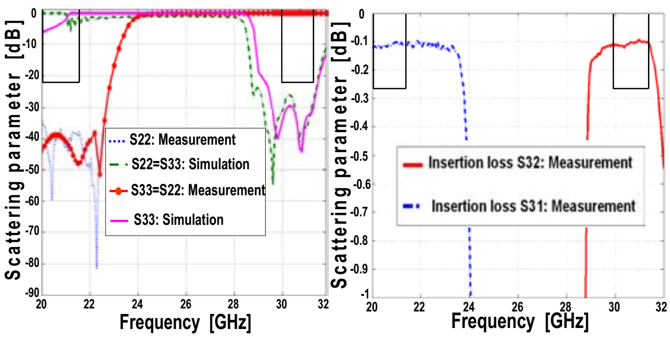

Fig.4. (a) Relection coefficient. b) Insertion losses

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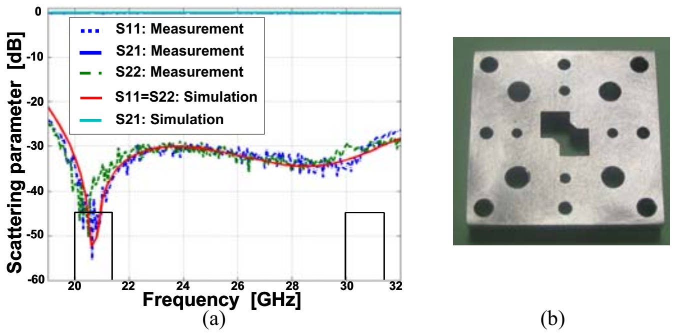
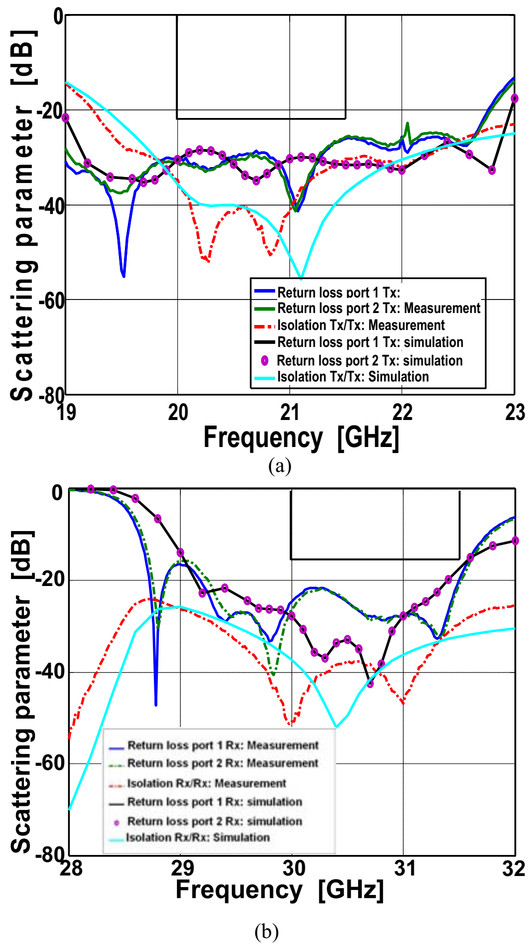
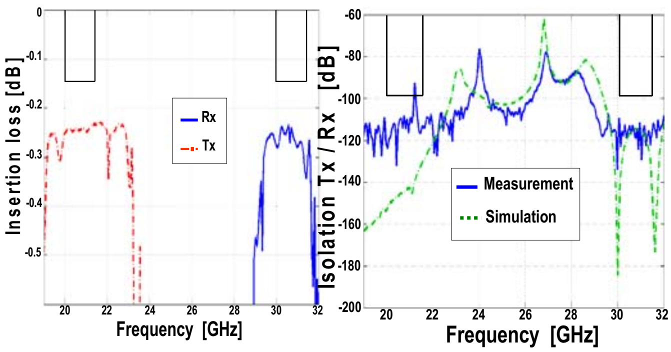


Fig.5. 90 degree electric field rotator. a) S parameter. (b) Machined prototype



Fi.6. Scattering parameters of the 4-ports subsistem. a) Low frequency band (Tx). b) High frequency band (Rx).



(c) (d)

Fig.7 Scattering parameters of the 4-ports subsistem. c) Insertion loss. d) Isolation Tx / Rx

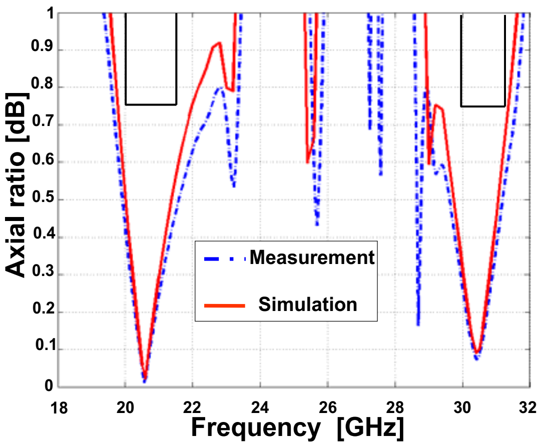


Fig.8. Axial ratio in both frequency bands (20-21.5GHz and 30-31GHz).

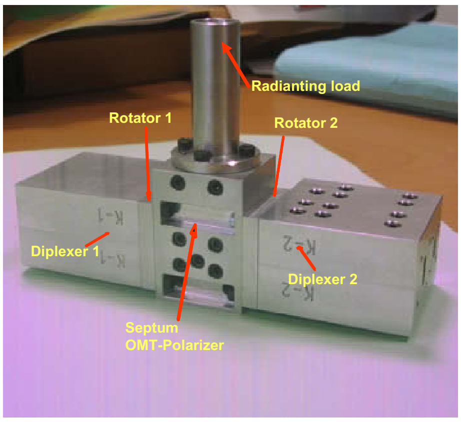


Fig. 9. Photograph of the fabricated prototype of the K/Ka 4-ports dual circular polarization feed subsystem network.

We found that measurements closely follow the simulation results performed by Mician-μWave-Wizard tool [10]. Fig. 6 to Fig.8 present the return and insertion losses, the axial ratio and the isolation in both frequency bands of interest. From the previous graphs, the 4-ports prototype exhibit very good performances: the return loss is better than 25dB, the insertion losses are about 0.25 for both pairs of signals, the isolation Tx / Tx and Rx / Rx is about 40dB, the isolation Tx / Rx is better than 110dB, and the axial ratio is always maintained below 0.4dB in both frequency bands. An assembled prototype of the whole 4-port subsystem is shown in fig.9.

IV. Conclusions

We have presented the design, construction and test of a K/Ka 4 - port dual circular polarization feed subsystem taking into account dimension constraints for easy and low cost production. This compact 4 - port subsystem provides return losses better than 25dB in all electric ports, insertion losses less than 0.25dB, isolation (Tx/Tx and Rx/Rx) greater than 40dB, isolation Tx/Rx greater than 110dB, and an axial ratio always maintained below 0.4dB in both frequency bands of interest. If we evaluate in terms of the bulkiness, the system presents an extremely reduced size compared with the subsystems published in the literature. Furthermore this 4-port network can be easily scaled to the millimeter and sub-millimeter frequency bands without significant extra difficulties.

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