Ku & C BAND SOLID STATE SWITCH MATRIX FOR SATELLITE PAYLOADS USING LTCC MULTILAYER SUBSTRATE

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Abstract

This paper describes the design and development of Ku and C band solid state switch matrix for multimedia satellite payloads. The design, through the use of advanced packaging techniques, allows significant savings on mass and volume with respect to traditional electromechanical switches while guaranteeing a comparable reliability.

Introduction

In the last years the satellite applications have seen a strong increase in the space hardware demands mainly for commercial communication services. Present satellite applications, both for commercial communication services and for scientific missions, demand for reduction of dimension and weight, lower recurring costs, improved reliability and high performances. The market demand for new services implies a fast evolution of the satellite configuration and architecture. Basic trends are the communication to/from ground at higher frequencies, increase in the payload capacity, the use of OBP (*On-Board Processing*) and baseband on-board switching network, the need for crosslink communication to relay intersatellite data. In addition to the said *growth in number of transponders per satellite*, the trend towards *multibeam payloads with high number of spot beams and frequency reuse*, together with the need for *a high flexibility on the up&down links frequency plans, allowing adjustment of the capacity allocation*, justify a development effort in the area of the switching provisions foreseen for reconfiguration as well as redundancy.
Advanced technologies like GaAs MMIC, Microwave Hybrid Integrated Circuit packaging, advanced ceramic substrates for high density multi-chip modules (thin and thick film on Al_2O_3, LTCC) allow to realise solid state switch matrices with significant reduction of size and mass and higher reliability

Ku & C Band switch matrix design

The Ku band switch matrix has been developed for a multimedia payload to perform the connection between 10 RF input signals coming from the RF Front End (RFE) and 12 demodulation units (UMCD); 10 of the latter are used as nominal units and the other 2 operate for redundancy purposes. The same type of matrix allows similar connections in a section of the payload which works in C band.
The unit has 10 RF inputs and 12 RF outputs and any input may be connected to three outputs to ensure the proper connections between the RFEs and the UMCDs in case of failure of two UMCDs. The block diagram of the matrix is shown in fig.1. In table 1 the principal specifications of the matrix are reported
The major issue of this kind of unit at these frequencies is the isolation. Each MMIC switch guarantees 30 dB of isolation so for each switched off path the theoretical isolation is 60 dB. To have a real isolation which is compliant to the specification it is very important to minimise the unavoidable coupling between different RF paths in the cavity. As it is possible to see from the block diagram, when using a planar structure some intersection between RF paths are necessary. These intersections are very critical, in fact it is not possible to realise them with simple airbridges because they don't guarantee the necessary isolation. So a three-dimensional structure has been designed: in fact with this one the intersections are avoided by using microstrip and stripline on different planes; this structure may be realised with multilayer LTTC substrate.

The LTCC substrate, in addition to its suitabilility for this microwave application, is convenient in that it allows also to realise on a unique ceramic both microwave and control sections. The RF cavity is isolated with a kovar frame brazed on the top of the ceramic.

The use of a single substrate, in addition to cost reduction, allows more flexibility in the DC connection. In fact it must be considered that each MMIC switch needs six DC controls: such a large number of connections can't be placed on the same plane as the RF paths; using this substrate it is possible with via holes to bring the controls on lower planes isolated from the RF part. Moreover the use of coaxial feedthroughs from the control section to the microwave cavity is avoided.

The most critical points for the RF path are the transitions between microstrip and stripline. In order to properly design them, electromagnetic simulations have been performed; in fig.2 and fig. 3 a picture of the transition and the results of the simulation are respectively shown.

As it is possible to see from fig. 2 a reactive element, a microstrip stub, has been placed close to the transition to compensate the inductance of the via hole and of the wire bonding [1]. To properly isolate the striplines from the rest of the substrate additional ground-via holes has been placed adjacently to the stripline; the distance among the ground vias and the distance between this ground-vias barrier and the stripline, are also parameters which have been optimised [2].

On the basis of these simulations an SP2T block has been realised. This block, whose schematic and picture are respectively shown in figure 4 and figure 5, represent the building block of the whole RF part of the matrix which will be constituted of a serial repetition of it.

Experimental result*s*

The building block has been tested and the results are reported in the next figures. The fig. 6 and fig. 7 show the insertion loss of the two RF paths in Ku band: the differences in the value are primarily due to the length difference. Fig. 8 shows Input Return Loss and the Isolation in Ku band, fig. 9 shows the Insertion Loss of a path in C band and fig 10 the Input Return Loss and the Isolation in C band. The unavoidable cross-talks have reduced the isolation, especially in Ku band, but however all the values are in the specification.

Future works

On the basis of the results of the RF building block the next step is the realisation of the whole switch matrix which will be constituted of a RF section including a serial repetition of the building block and a control section. Both sections will be placed on the same LTCC multilayer substrate which will be epoxy attached on a kovar housing

Conclusions

Design and performance of a solid state switch matrix, used for redundancy and reconfiguration of demodulation resources on board a multimedia payload, was demonstrated. Large savings in terms of mass are achieved with the solid state approach with respect to traditional solutions. The design employs LTCC as a medium for both microwave transmission and for integration of control circuitry.

References

[1] W. Simon et al. "Interconnects and transition in Multilayer LTTC multichip modules for 24 GHz ISM-band applications" – 2000 IEEE MTT-S Proceedings

[2] W. Simon et al. "Design of passive components for K-Band Comunication modules in LTCC environment " – 1999 International symposium on Microelectronics Proceedings

Parameter	Unit	Specification
Frequency	GHz	4.8 – 6.2 , 10 - 13
Insertion Loss	dB	<8
I/O Return Loss	dB	>15
Isolation	dBc	≥40

Table 1: Spec of the matrix

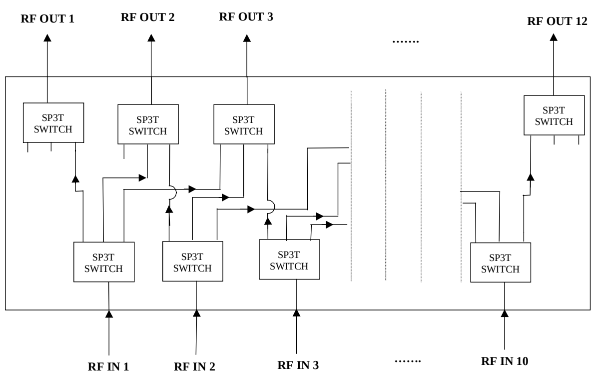


Figure 1: Block diagram of the matrix

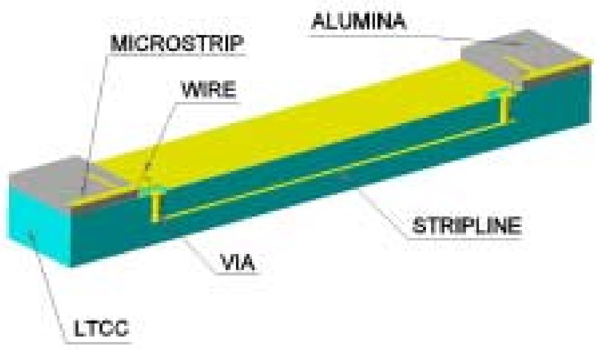


Fig. 2 : ustrip – stripline – ustrip transition

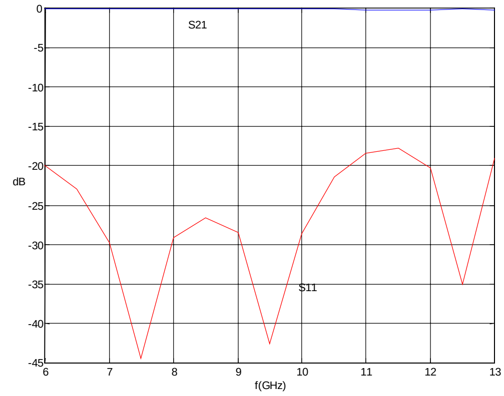


Fig. 3: e.m. simulation of the transition

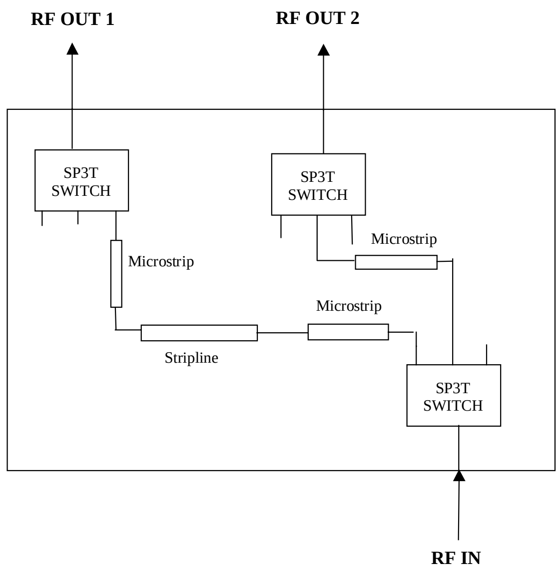


Figure 4: Block diagram of the RF building block

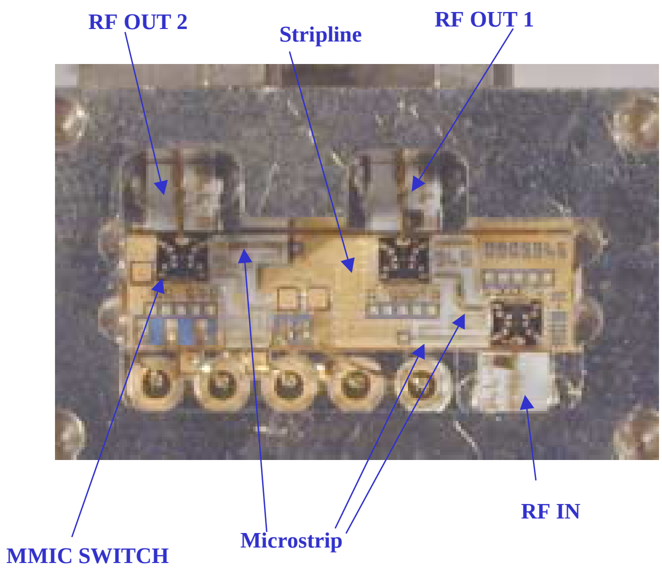


Figure 5 : Picture of the RF building block

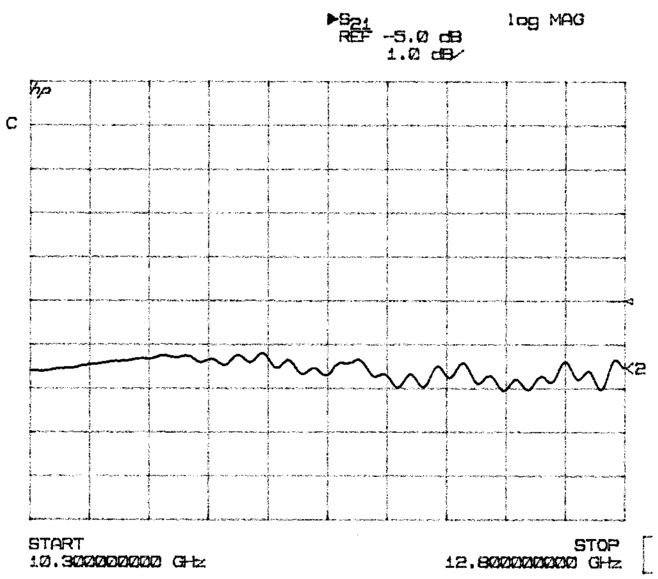


Figure 6: Switch matrix insertion loss through µstrip RF path in Ku band

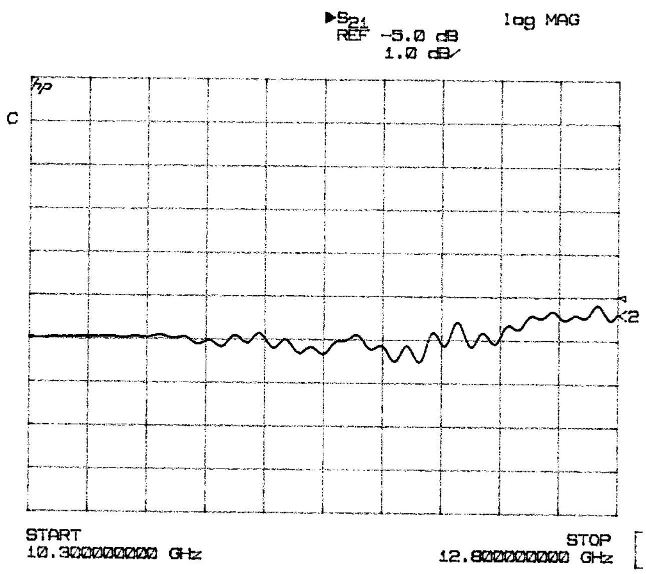


Figure 7: Switch matrix insertion loss through µstrip-stripline- µstrip RF path in Ku band

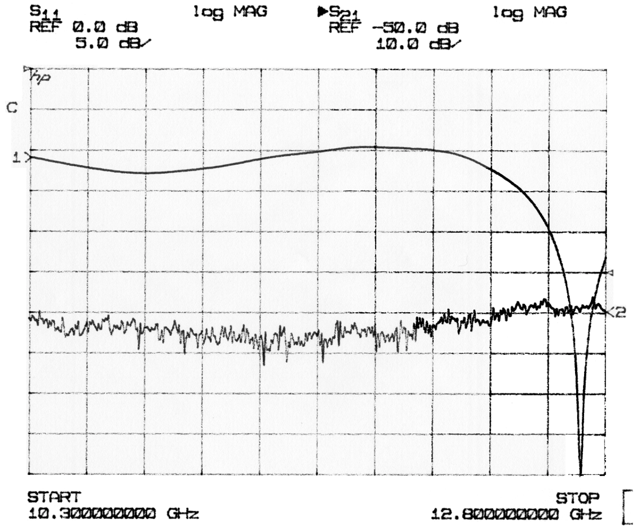


Figure 8: Input Return loss and Isolation in Ku band

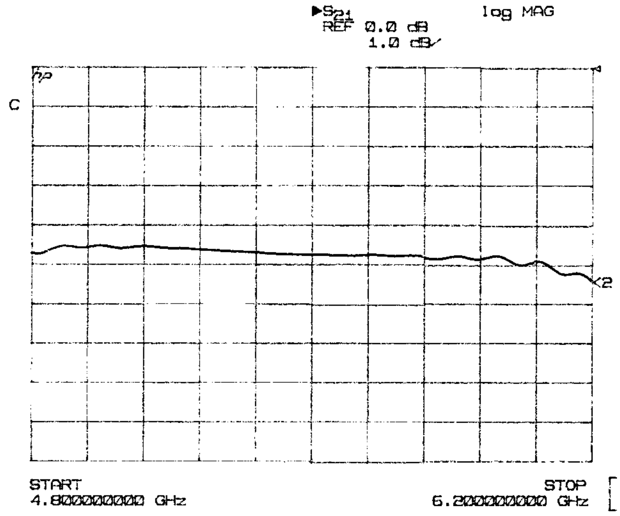


Figure 9: Switch matrix insertion loss through µstrip-stripline- µstrip RF path in C band

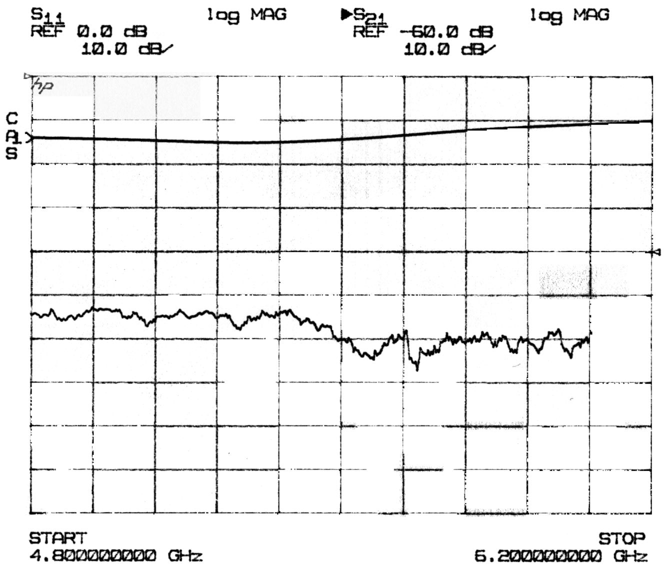
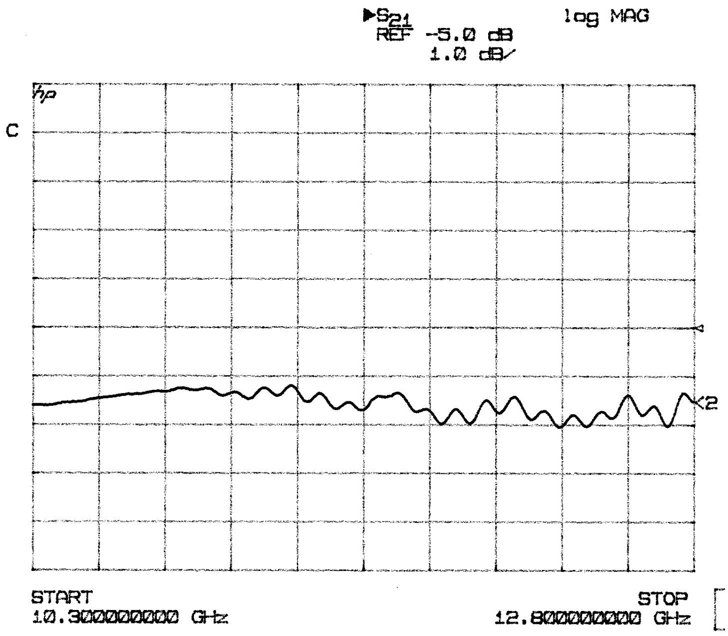


Figure 10: Input Return loss and Isolation in C band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