Low losses power distribution network at X band in stripline

José Manuel Inclán Alonso(1), José Manuel Fernández González(1), Manuel Sierra Pérez(1)
{chema, jmfdez, m.sierra.perez} @gr.ssr.upm.es
(1) *Radiation Group. Signals, Systems and Radiocommunications Department*
Technical University of Madrid . Avda. Complutense, 30. 28040. Madrid. Spain.

***Abstract*- An asymmetric stripline is proposed in this paper. The main aim of this line is to distribute the power among subarrays in an array with minimum losses. Several vertical transitions to subarrays are shown besides some network designs at X band for a square array for satellite communications.**

I. INTRODUCTION

Nowadays low profile array antennas are being more and more used substituting traditional parabolic antennas in satellite communications. The problem is that the losses in traditional printed technologies are very large, making impossible to fulfill with the ITU-R recommendations for satellite communications.

Waveguide technology could be an option for a parallel distribution network. The problem is that the width of the waveguides is bigger than the width of printed networks, making it difficult to design a complex network. Another problem is that to assure a good contact in waveguide technologies between the two halves is critical, making the network more expensive and heavier.

In this context, to reduce the conductor losses in printed technologies, the height or the distance between the line and the ground plane must be increased.

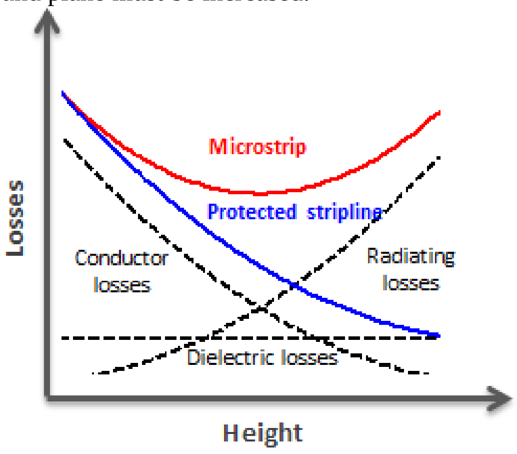

Fig. 1 Losses in printed technologies

To increase the distance between the line and the ground in microstrip technology, we can use either a higher substrate, increasing the weight and the price of the antenna, or a suspended microstrip, using foam to separate a thin substrate from the ground.

The disadvantage of microstrip technology is that besides the conductor and dielectric losses, the line also has radiation losses. This sets a limit in how much we can reduce the losses in the structure as it is shown in Fig. 1. Moreover increasing the distance between ground and line, the coupling between lines is also increased.

On the other hand in stripline technology there aren´t radiating losses so the total losses can be reduced more than in microstrip technology.

II. STRIPLINE TECHNOLOGY

Striplines can be symmetric or asymmetric. Symmetric striplines are more used for general purposes whereas asymmetric striplines are more used to make low losses power distribution networks. In asymmetric striplines the line is printed in a thin substrate. This substrate is supported by foam sheets or metallic walls screwed to the two ground planes as it is shown in Fig. 2. It is called asymmetric because the conductor is closer to one of the two ground planes.

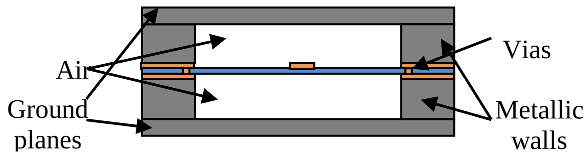

Fig. 2 Example of asymmetric stripline

The main mode in asymmetric striplines is a Quasi-TEM since there are two dielectrics, the substrate with the printed lines and air or foam. Since the ratio between the substrate height and the air/foam height are usually more than ten, the permittivity is very close to the permittivity of the foam/air.

Biplate TE modes are also supported in stripline technology. These modes are generated in the vertical transitions and in some discontinuities in the line as it is shown in Fig. 3. This TE mode can be cut off with metallic walls along the line as in the Fig. 2. In this case the stripline is called shielded stripline.

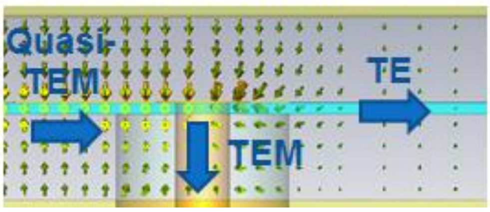

Fig. 3 TE mode generation in vertical transitions

III. TRANSITIONS

To connect the power distribution network to the subarrays with the radiating elements, vertical transitions are needed. These vertical transitions have to be pluggable in some way because nothing can be soldered between the subarrays and the power distribution network since the distance should be small in order to have a low profile and low losses antenna.

Two approaches to connect subarrays and power distribution network have been followed. The first one is using commercial SMP coaxial connectors (pluggable connectors) and the second one is to design an ad-hoc vertical transitions.

Finally the global input/output of the power distribution network /antenna is done with a regular SMA connector.

A. Stripline-Coaxial SMP

The problem with commercial SMP coaxial connectors is that they need to be placed in microstrip technology so a transition between macro stripline and microstrip is necessary (see Fig. 4). This transition has to be designed very carefully since the ratio between the width of the stripline and the width of the microstrip is close to ten.

The stripline width is reduced changing the impedance of stripline from 50 Ω to 70 Ω as it is shown in Fig. 4. Then this change has to be reverted in a small microstrip network where the SMP connector is soldered.

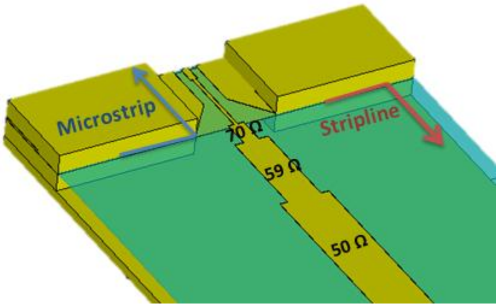

Fig. 4 Macro Stripline-microstrip transition

Several prototypes of these transitions have been manufactured. The measured losses of the SMP connector plus SMP to SMA transitions are around 0.4-0.5 dB. The losses in the stripline-microstrip transitions are around 0.2 dB. Total losses and the matching of a through with two transitions are shown in Fig. 5. The losses of the through are around 1.5 dB with a matching lower than -20 dB at X band.

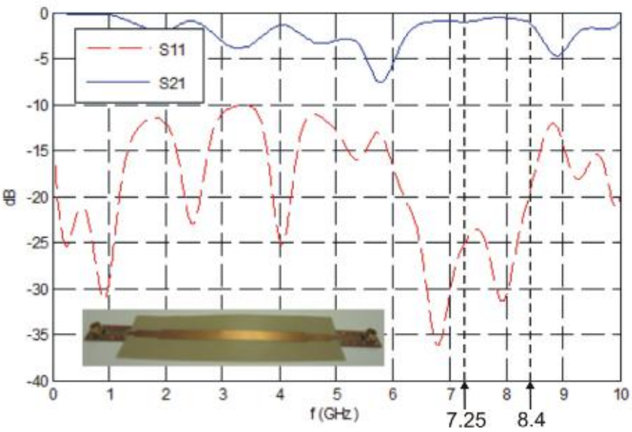

Fig. 5 Measured S Parameters of SMP-Stripline transition

Several problems with SMP connectors have been detected. The first problem is that the connector is very fragile, very easy to break when they are plugged. The second problem is that there is no point in using a complex low losses structure if the losses in the connectors are much bigger.

B. Stripline-Coaxial SMA

Since the height of the stripline is high, the transition from the TEM mode in the coaxial to the Quasi-TEM mode in the stripline has to be done smoothly. That is why the edge of the metallic piece has to be rounded. The corners in the piece have to be also rounded in order to avoid diffraction. A small segment of stripline with a different width is used at the beginning of the transition to improve the matching as it is shown in Fig. 6.

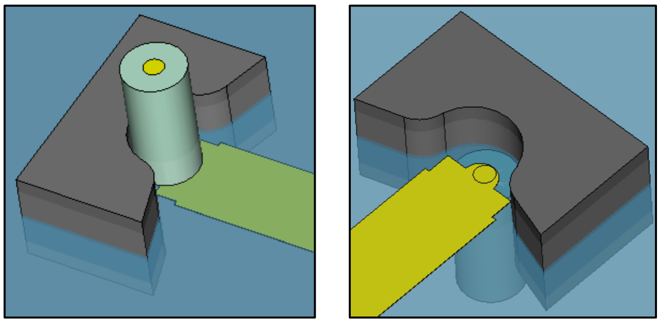

Fig. 6 Macro stripline- Coaxial SMA transition

Fig. 7 shows the matching of a SMA-stripline transition. The influence of the solder process is critical and has to be done carefully in order to have a good matching.

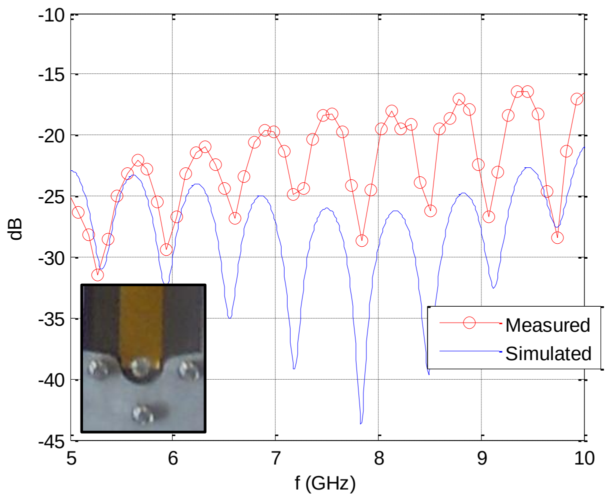

Fig. 7 Measured and simulated matching of a SMA-macro stripline transition

C. Stripline- ad-hoc connector

A new connector has been developed. The main aims of this connector are to connect the stripline to a micrsostrip without metal contact between the inner conductors and to reduce the losses as much as possible.

The connector has two parts. The first part is a coaxial line with an inner conductor diameter of 3 mm, the inner conductor is supposed to be soldered to the stripline. The second part is a smaller coaxial line with an inner conductor diameter of 1.3 mm; similar to a commercial SMA transition, the inner conductor of the second part is supposed to be soldered to the microstrip network. Both coaxial lines have

PTFE as dielectric. A scheme of the connector is shown in Fig. 8.

To achieve the continuity between the inner conductor soldered to the stripline and the inner conductor soldered to the microstrip a virtual short circuit is used. Finally a small length of coaxial line with high impedance is used to improve the matching.

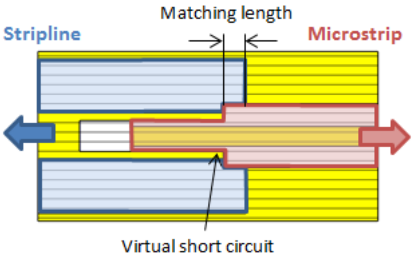

Fig. 8 Own connector scheme

Fig. 9 shows the construction of the first prototype of the coupled connector.

Fig. 9 Own connector design

The transition from stripline to the own connector is shown in Fig. 10. This transition is easier to design than the previous ones since the connector is bigger.

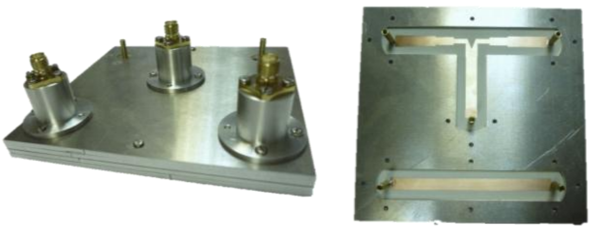

Fig. 10 Macro stripline with own connectors

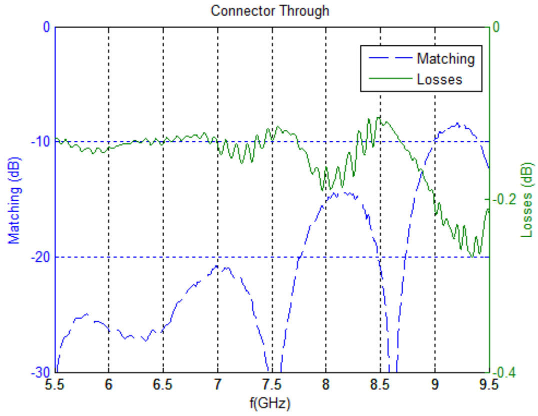

Fig. 11 S-parameters of a through with own connectors

The S parameters of a through with the new connectors are shown in Fig. 11. The losses in the through are lower than 0.15 dB, these losses are much smaller than the losses in the through done with commercial SMP connectors that were bigger than 1.5 dB.

IV. Designs

In the following, some examples of macro stripline are shown, explaining the characteristics and the problems found in each design.

A. First design

The first design is shown in Fig. 12. This network is used to distribute the power to an antenna of 4 by 4 subarrays with some tapering, feeding with more power the subarrays in the center and with less power the subarrays in the corners.

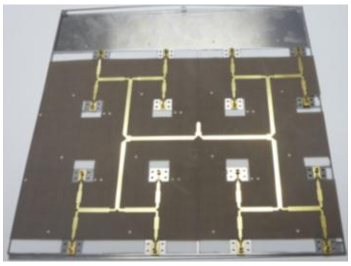

Fig. 12 First prototype of power distribution network

As it is shown in the transmissions of Fig. 13 this first prototype did not work due to the presence of TE modes generated not only in vertical transitions but also in other parts of the line. To solve this problem, a shielded stripline network has to be used as it has been done in next prototypes (see [1]).

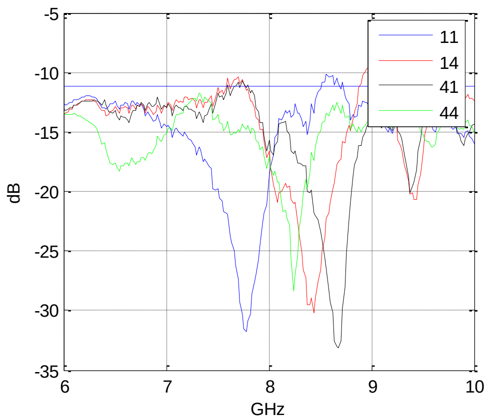

Fig. 13 Measured transmissions in the first prototype of the power distribution network

B. Second design

The second design consists in two networks of 3x3 outputs with tapering. Each network is for one polarization. In this case, since all the outputs need to have the same phase, meander lines have been used. To avoid the problems detected before with TE modes, the line has been protected with metallic walls (see Fig. 14).

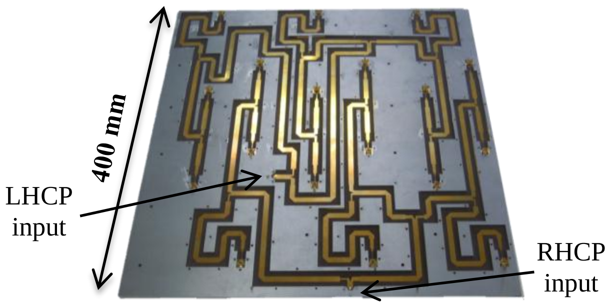

Fig. 14 Second design of power distribution network

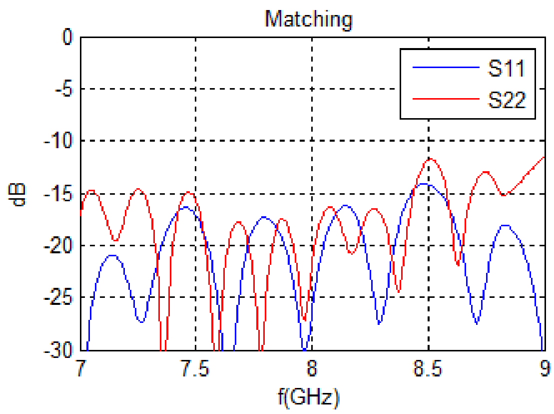

Fig. 15 Matching of the second design

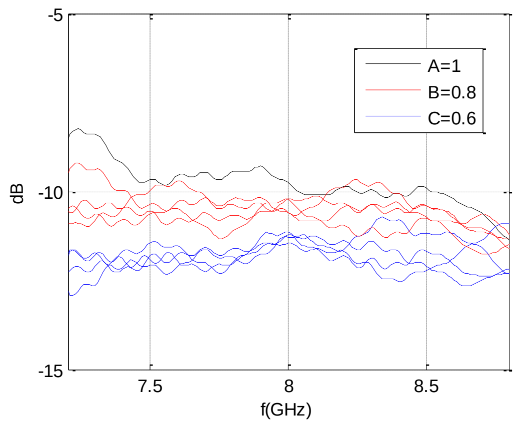

Fig. 16 Transmissions to each subarray of the second design

As it is presented in Fig. 15, the matching in the two polarizations is better than 15 dB in the whole X band. The transmissions of Fig. 16 proves that the tapering is well done since the corner subarrays receive in average 1 dB less than the one in the center. The losses of the structure are lower than 1.5 dB for one polarization and lower than 2 dB for the other one. More results of this network can be seen in [2].

C. Third design

There are three main differences between the third and second design. The first one is that in the third design ad-hoc connector system will be used instead of commercial connectors as it has been commented before. The second one is that sequential rotation technique is used, meaning that each subarrays will be rotated 90º and the feeding network compensates this rotation with a phase shift of 90º as it can be observed in Fig. 18. The third difference is that multisection power dividers are used instead one section power dividers to increase the band width as presented in Fig. 17.

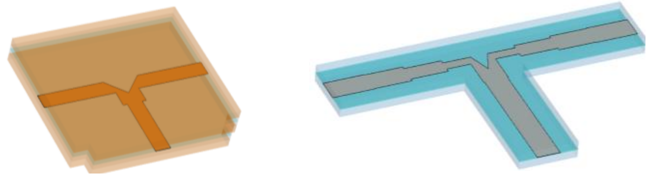

Fig. 17 One section and three sections T power dividers

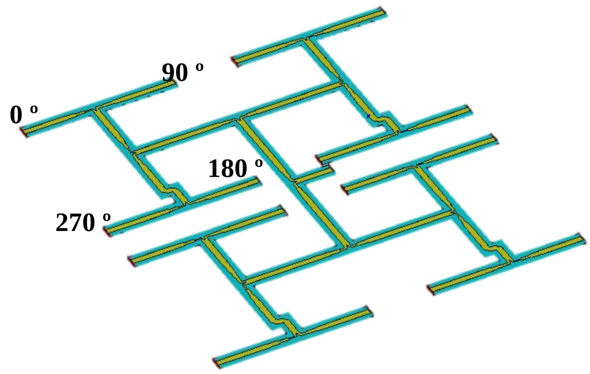

Fig. 18 Design of the third power distribution network

V. CONCLUSIONS

Practical designs of low losses power distribution networks have been presented. Two prototypes have been shown and the third one will be presented at the conference. Some problems in the first prototype have been presented that are solved in second prototype. The good performance of the second prototype has been presented. A third prototype of shielded stripline network with some improvements has been sketched.

ACKNOWLEDGMENT

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