SUITABLE PLANAR TRANSMIT-ARRAYS IN X-BAND

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ABSTRACT

This paper presents two planar transmit-array configurations with one ground plane. The requirements of the radiating elements are discussed and the design of two patch based radiating elements, which are considered suitable for a X-Band Transmit-Array, is presented. The measurements of the manufactured prototypes are included.

1. INTRODUCTION.

Planar arrays are a very interesting option to substitute reflector antenna because of their well-known characteristics of low profile, potential low cost, reliability and flexibility in achieving contoured beams and multiple beams with a simple planar geometry. Suitable solutions for space applications have been proposed using reflect-arrays with countered beams and multibeam. Another proposed solutions are transmit arrays. In this case, the antenna acts as a lens. This consist of a periodic planar array having two patch antennas connected by a line. One element receives the signal from –z direction and the other transmits the signal in the +z direction. By a proper selection of the phase delay in the connection line, the phase distribution in the transmitting array can be set. In an equal output phase configuration the transmitting array behaviour would be similar to the obtained with a parabolic reflector, having the advantage of removing the feed blockage. Moreover, lenses are less sensitivity to thermo electrical distortions. While transmit array are less volume and mass than conventional lenses. However the design of the proper and suitable radiating elements to obtain a transmit array is not trivial because many difficulties appear due to the fact of the radiating configuration in the positive and negative directions. In the literature several configurations have been proposed. One of them is based in two slot coupled-patches [1], however, when the authors try to design a transmit-array using this configuration in the X-band, no suitable solutions were found because the parallel plate waveguide that results from the presence of the two ground planes of the patches.

In this paper two radiating element are proposed: one directly fed patch and one slot coupled patch. These two element drive to two different transmit-array configurations. The first one use as transmitting and receiving element the direct fed patch. And the other uses the direct fed patch and the slot coupled patch. In both of them, only one ground plane is found, having been removed the parallel plate waveguide.

The design, simulations and measurement of these elements for a X band transmit-array are presented in this paper. Other critical issues that appear in a practical design such as parasitic radiations are evaluated. These elements are considered suitable for a practical transmit array design.

2. TRANSMIT-ARRAY ELEMENTS

This section describes the single elements and components as well as their design criteria to be used in a transmit-array.

The selected band for this design is 9.5 GHz to 9.8 GHz for a typical X-Band SAR application.

To reduce the mismatching losses, considering that a independent design of the elements is being performed, considering also that any phase shift can be found in the delay lines and that space considerations can drive to asymmetric structures, the return losses for the radiating element specification has been set to -21 dB. The design band has been extended to 9.4 GHz-9.9 GHz to take into account the substrate tolerances.

2.1. Directly fed patch

To obtain a transmit array geometry with just one ground plane a directly fed patch is necessary. The input microstrip line connects to the radiating patch, having both line and patch the same ground plane.

Therefore spurious radiation of the microstrip line will be found in the region of the space in which the patch radiates. To reduce it, the use of a high dielectric constant and low height substrate is advisable.

Directly fed patches are very narrow band structures, and the bandwidth is decreased by reducing substrate height or increasing substrate dielectric constant. Two different aims are found in the same substrate configuration, low radiation for the microstrip, big radiation for the patch.

As consequence of this, to obtain the desired bandwidth with a high matching level a second stacked patch is required. This second patch can have a low dielectric constant substrate and can be located at a greater high. As long as the second (upper patch) is still coupled with the lower patch and consequently it radiates. Due to manufacturing considerations this second patch is printed on a substrate and this substrate is placed over the lower patch using spacers, having an air layer in

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between them. This air layer makes that the input line behaves as a microstrip form impedance and propagation features.

Fig. 1 shows the resulting geometry for this patch. Table 1 lists the parameters of the dielectrics used in this patch while the conductor geometry parameters are listed in Tab. 2.

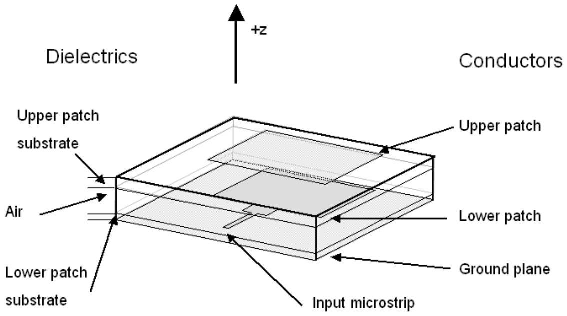

Figure 1. Directly fed patch

Table 1. Directly fed patch substrates.

Description	Material	Dielectric constant	Thickness (mm)
Upper patch substrate	Arlon AR-25N	3.38	0.7620
Spacer	Air	1.0	2.0
Microstrip and lower patch substrate	Arlon AR-25N	3.38	0.508

Table 2. Directly fed patch conductor dimensions

Description	Length (mm)	Width (mm)
Upper patch	8.39	10.07
Lower patch	7.75	9.30
Matching capacitors	1.85	0.76
Input line: Microstrip (72 Ω)		0.6

2.2. Slot coupled patch.

A second radiating element has been developed. This is a patch antenna coupled to the line in the previous subsection.

Aperture coupled patches are wideband, so, in principle a single patch could be used for this application. However the slot produces an undesired radiation which in classical antennas is back radiation and it does not degrade the main radiation characteristic because the existence of the ground plane.

In a transmit array configuration, this back radiation has to be kept as low as possible, since the back radiation of one element (receiving or radiating) disturbs main radiation of the other element (transmitting or receiving). Therefore the slot size has to be kept as small as possible. This is achieved by having one patch with a substrate with low height and a high dielectric constant. As consequence of this, the resulting patch has a very narrow bandwidth. Therefore, to obtain the desired bandwidth a second stacked patch is required. The resulting geometry is then very similar to the one obtained for the previous patch. The outer patch is printed on a substrate which is located over the inner patch using spacers and having air layer in between them.

The resulting structure is multilayer. Because some prototypes are going to be developed, and following manufacturing and technological considerations. at the time of this design a 50 microns air layer was added between the ground plane and the inner patch substrate.

Fig. 2 shows the geometry of this patch. In this figure, the radiation direction is –z. Tab. 3 lists the substrates used for this patch, while Tab. 4 lists the geometry of the conductors.

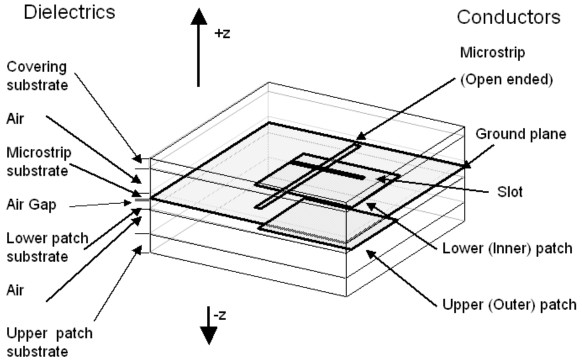

Figure 2. Slot coupled patch.

Table 1. Slot coupled patch substrates.

Description	Material	Dielectric constant	Thickness (mm)
Cover substrate	Arlon AR-25N	3.38	0.7620
Spacer	Air	1.0	2.0
Microstrip substrate	Arlon AR-25N	3.38	0.508
Ground plane			
Gap	Air	1	0.050
Inner patch substrate	Arlon AR-25N	3.38	0.7620
Spacer	Air	1.0	2.0
Outer patch substrate	Arlon AR-25N	3.38	1.524

Table 2. Slot coupled patch conductor dimensions

Description	Length (mm)t	Width (mm)
Input line: Microstrip (72 Ω)		0.6
Slot	.5	6.18
Inner patch	7.1	8.52
Outer patch	6.8	8.16

2.3. Single element simulations.

Fig. 3 shows the return losses simulations of the previous elements. This simulation has been obtained with ADS2003 and ADS2005 Momentum. This software performs as full wave analysis of the structure using the Method of Moments. It can be seen that the design widely match the specifications.

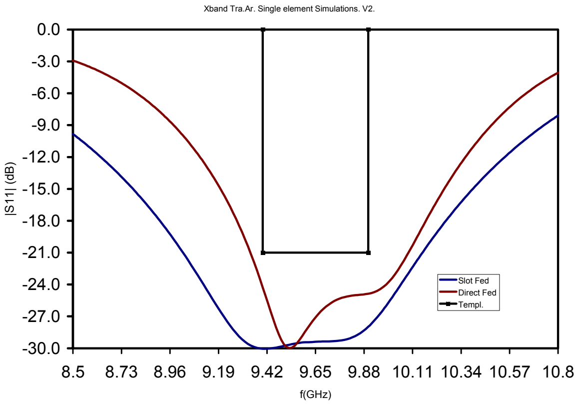

Figure 3. Return loss simulations of both single radiating elements.

In Fig. 4 the main cuts of the radiation pattern of both elements at the frequency of 9.5 GHz are shown. The coordinate system used is the one depicted in Fig. 1 and Fig. 2. That is why the main radiation of the slot coupled patch is found in θ=180º. It can be seen that the back radiation of the slot coupled patch is about -22 dB. The directivity values are 7.5 dBi and 8.3 dBi for the slot coupled patch and the direct fed patch. Both values and the bandwidths will be used for the array design.

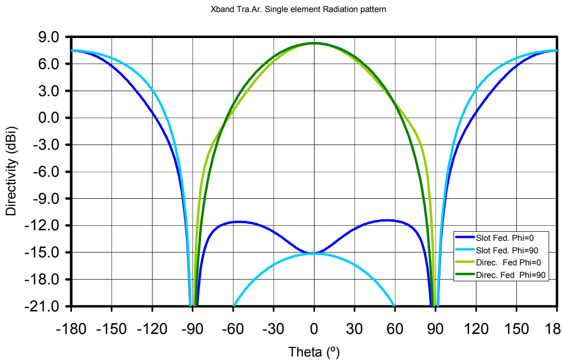

Figure 4. Radiation pattern of both single radiating elements at 9.5 GHz.

2.4. Delay line components.

To obtain the proper delay in the transmit array, delay lines are required to connect the radiating and transmitting elements. Microstrip bends have been designed for this geometry. Also a microstrip via has been designed. Following space considerations these designs are not included in this paper.

3. TRANSMIT ARRAY CONFIGURATIONS

By a proper combinations of the previous elements two transmit array with a single ground plane can be found. To allow room for delay lines routing an initial cell size of 24 mm has been chosen. (0.77 λ). Other considerations such as periodicity, coupling between element and aperture efficiency have to be into account when the single cell is chosen.

The first transmit array single element configuration is obtained by using two directly fed patches with common ground planes and connecting the lines by mean of a via. This geometry is depicted in Fig. 5. This concept has been presented in [2].

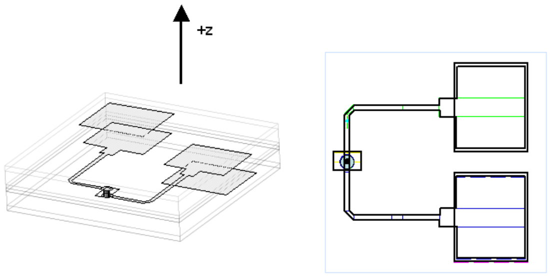

Figure 5. Transmit array cell using to directly fed patches.

By using a direct fed patch, let us say, as receiving element and a slot coupled patch as transmitting element a second transmit-array configuration is obtained. The output line of one element is used as the input line of the other element, having the required length to obtain the desired phase shift. This cell is shown in Fig. 6 and is similar to the one presented in [3].

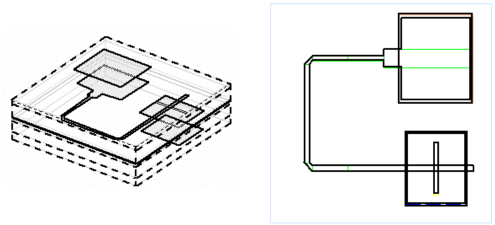

Figure 6 Transmit array cell using a directly fed patch and a slot coupled patch.

Both structures present some advantages and disadvantages comparing each to other.

The first structure has a lower bandwidth, so it can be more sensitive to possible tolerances. However, it has more space for delay lines, that can be necessary to obtain true time delay transmit array configurations, and almost a symmetric geometry can be obtained.

On the other hand, the second structure has bigger bandwidth, so it is more robust against tolerances and their mounting process is easier since no via circuits are required to be mounted. However, the back radiation of the slot can degrade the antenna performances.

4. PROTOTYPES.

In order to verify and validate the designs, several prototypes were manufactured and measured.

Fig. 7 shows a picture of them, where both radiating elements can be seen. This figure also shows the via prototype and bend line prototypes, as well as, a prototype with reference lines. For convenience, the input line impedance was set to 50 Ω and connectors were mounted, therefore a quarter wavelength section was included to transform the 50 Ω line to the patches input lines which has an impedance of 72 Ω. This transformer was added just for measurements but it is not necessary in the array antenna.

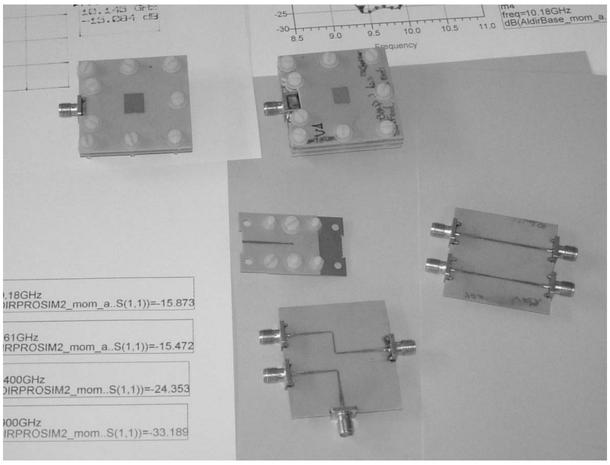

Figure 7. Prototypes of the elements. (From left to right and from top to bottom: direct fed patch, slot coupled patch, reference lines, line bends)

Fig. 8 shows the return losses measurements of the radiating elements. It can bee seem that the target values of matching and band are widely matched.

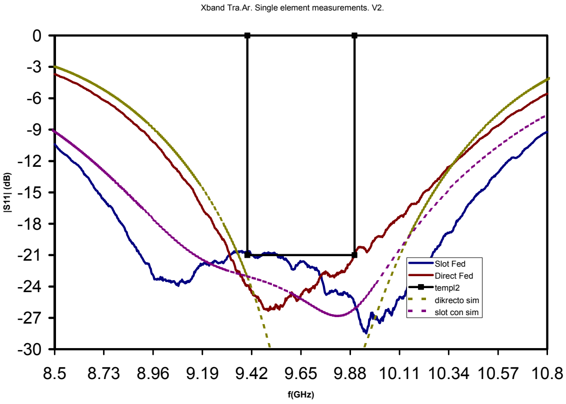

Figure 8. Measured return losses of the radiating elements.

5. TRANSMIT ARRAY.

The complete transmit-array design is out of the scope of this paper, however some comments have to be done. In the array configuration the coupling between element has to be considered. As consequence of this, the dimensions of the element presented previously can slightly vary, but this variation will be minimum or insignificant. In fact, as stated in [4] that mutual coupling can be neglected when the separation between adjacent patches is larger than 0.25 wavelengths in the dielectric as already used in printed arrays [5]. The cell size will be determined mainly by geometry considerations, radiation pattern specifications and antenna efficiency. For 24 mm cell size the separations between patches is about 16 mm, a value close to half a wavelength in the air. In any case, a first analysis approach can be done by considering how an element is loaded by its neighbors, considering nine elements in total, as shown in Fig. 9.

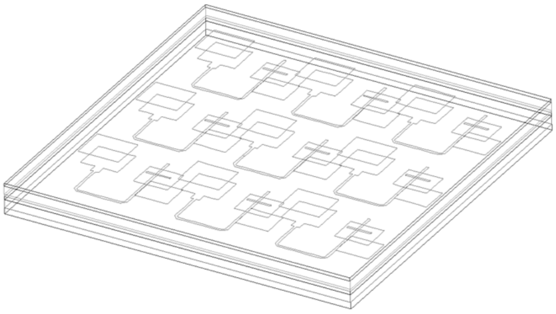

Figure 9. Coupling analysis geometry.

As reference, Fig. 10 shows the drawings of a transmit-array that is currently being manufactured.

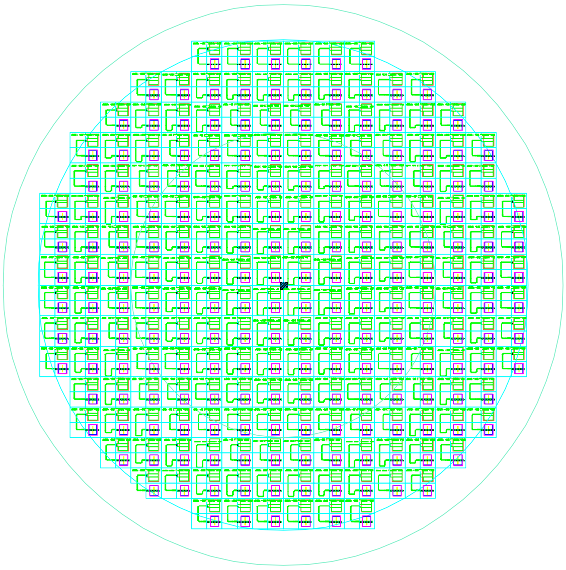

Figure 10. Transmit array drawings.

6. CONCLUSIONS

Two patch-based radiating elements that drive to two different planar transmit array configurations have been presented. Both of this configurations have just one ground plane and microstrip lines are used. This avoid the use of stripline and the parallel plate structure. Moreover, the proposed design pursue the maximum reduction of spurious radiations. This reduction is necessary because the lens working mode of this antenna requires control of the radiation in both directions (transmitting and receiving). The presented designs have been validated by prototype measurements and the obtained results widely match the specified requirements for the array.

7. ACKNOWLEDGMENTS

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8. REFERENCES

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