

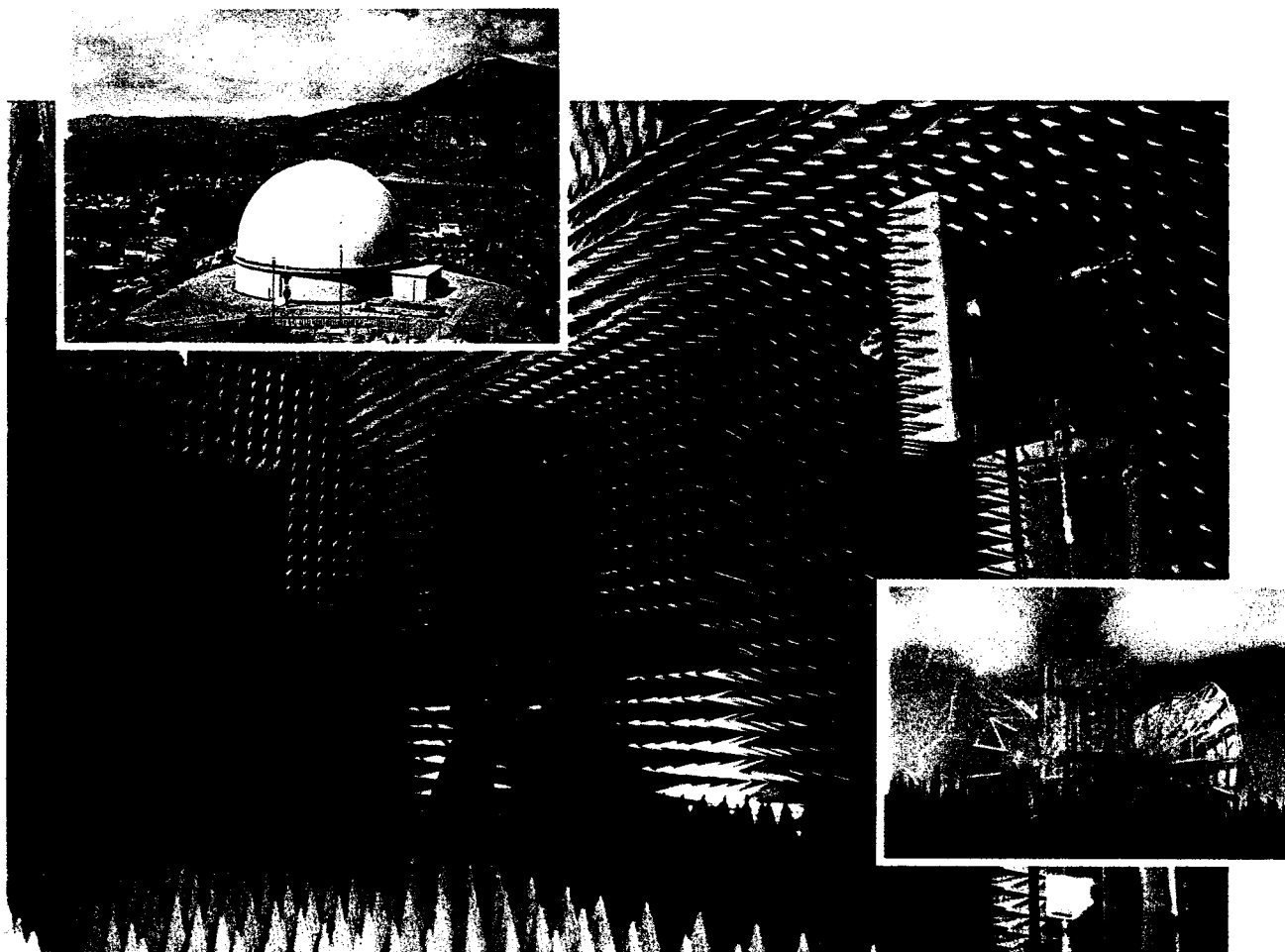
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## CONFÉRENCES

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## EXPERIMENTAL STUDY OF CURVATURE AND LINE WIDTH EFFECTS ON CHARACTERISTICS OF PRINTED ANTENNAS FED BY MICROSTRIP LINE

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### Abstract

The effects of curvature on the characteristics of a rectangular patch antenna printed on cylindrical body and fed by microstrip line are studied experimentally. The influence of the width of the microstrip line on the input impedance is also investigated. The results show that a very important difference appears and that the curvature of the patch and width of the line cannot be neglected.

### Introduction

Thin printed antennas can be conformed over the surface area of a vehicle (aircraft, missile, satellite, rocket ...) allowing minimum airstream disturbance. They are often associated in large arrays with a microstrip line fed network because of its simplicity and low cost. However, the increasing use of this type of antennas is often done considering that the curvature of the patch and the characteristic impedance of the feed line do not modify the behaviour of the radiating element. The purpose of this paper is to show an experimental study of these effects for which very few papers have been published [1-3]. The studied structure is a patch antenna on Duroid substrate. This element is fed at the middle of a side by a microstrip line (figure 1).

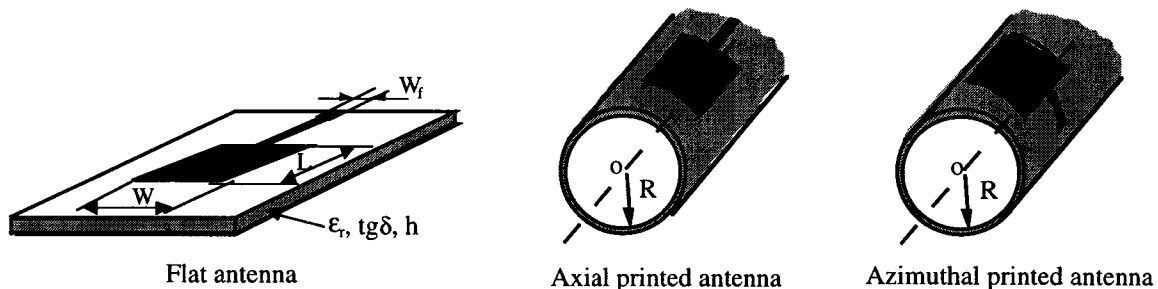


Figure 1: Various printed antenna fed by microstrip line

$\epsilon_r = 2.2$   $h = 0.762$  mm  $\text{tg } \delta = 0.001$   $W = 50$  mm  $L = 50$  mm

### Experimental results

The effects of the width is studied in four cases  $W_f = 2.29$  mm, 1.2 mm, 0.63 mm and 0.23 mm, corresponding respectively to the following characteristic impedances  $Z_c$ : 50, 75, 100, and 150  $\Omega$ . Each line's width is also studied in five cases of curvature, the flat case,  $R=10$  cm, 5 cm, 2.5 cm and 2 cm. The study is assumed for curvatures along the axis and the azimuth of the antenna (fig. 1). The measured input impedance is given at the plane junction between the fed line and the edge of the patch.

For example, figures 2 and 3 show the real and imaginary parts of the input impedance in the flat case for different values of  $Z_c$ . Figures 4 and 5 show the real and imaginary parts for different radii for a 100  $\Omega$  fed line. The measured resonance frequency is closed to 1.99 GHz in each case however there is a strong variation of the input impedance. We can notice that the real part of the input impedance decreases as the imaginary part when the characteristic impedance of the feed line or the curvature of the patch increases.

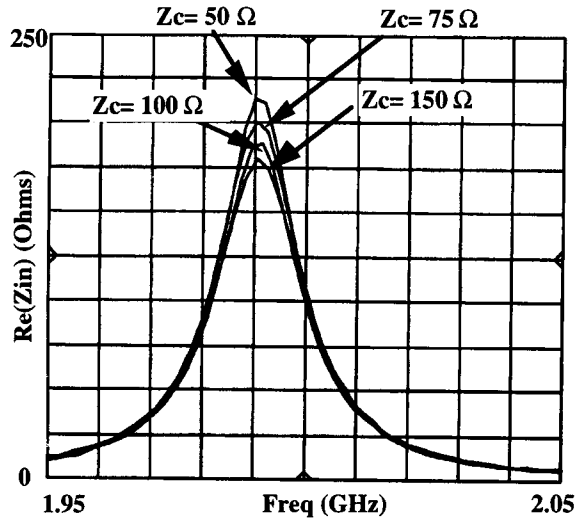


Figure 2: Real part of the input impedance in the flat case

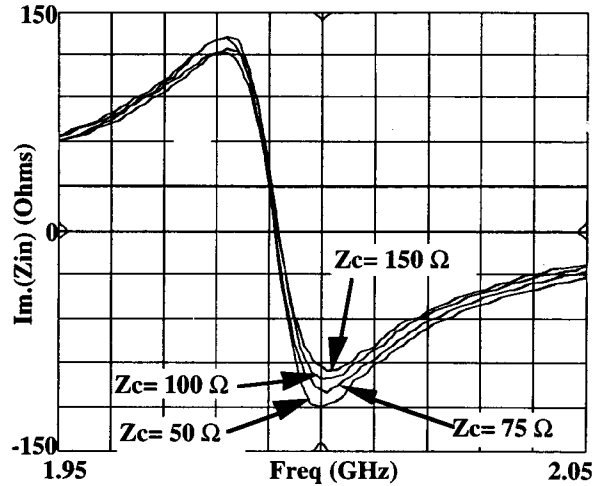


Figure 3: Imaginary part of the input impedance in the flat case

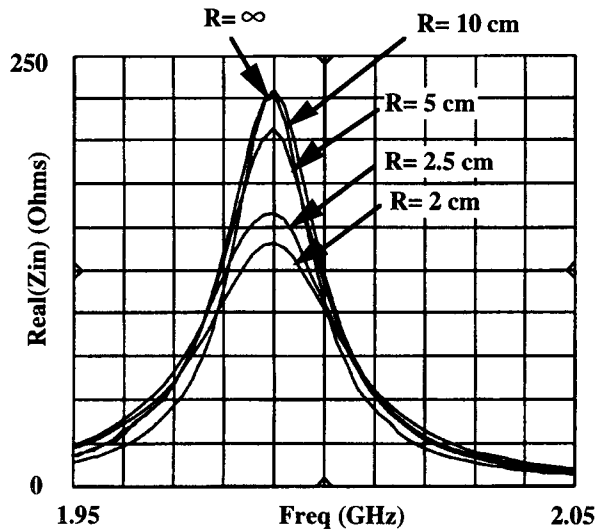


Figure 4: Real part of the input impedance for different radii (100  $\Omega$  fed line)

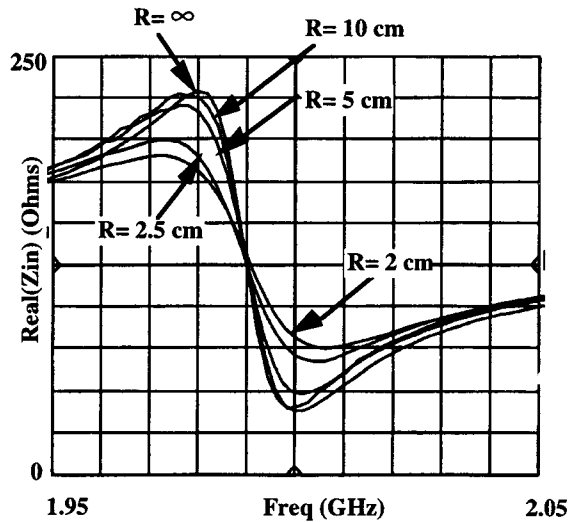


Figure 5: Imaginary part of the input impedance for different radii (100  $\Omega$  fed line)

### Axial case

All the results are resumed in Table 1 for axially oriented antennas. The differences in percent are calculated each time from the flat case (first column) and from the flat case when the antenna is fed by a 50  $\Omega$  characteristic impedance line (second column). This result is reported in figures 6 and 7. We can notice a fast variation of the real part of the input impedance for the small values of  $R$ . All the curves have however the same behaviour and maybe a simple polynomial expression function versus  $Z_c$  or  $R$  could be easily obtained. These polynomial approximations are a first step to establish simple variational expressions to describe the phenomena.

	$Z_c = 50 \Omega$ $W_f = 2.29 \text{ mm}$		$Z_c = 75 \Omega$ $W_f = 1.2 \text{ mm}$			$Z_c = 100 \Omega$ $W_f = 0.63 \text{ mm}$			$Z_c = 150 \Omega$ $W_f = 0.23 \text{ mm}$		
Radius	Max. Real ( $Z_{in}$ )	Diff. %	Max. Real	Diff. %	Diff. %	Max. Real	Diff. %	Diff. %	Max. Real	Diff. %	Diff. %
Flat case	<b>258.8</b>	0	240.6	0	-7.0	227.5	0	-12.1	215.6	0	-16.7
10 cm	231.0	-10.7	217.5	-9.6	-15.9	191.8	-15.7	-25.8	179.9	-16.5	-30.5
5 cm	203.8	-21.2	187.5	-22.1	-27.5	169.5	-25.5	-34.5	161.3	-25.2	-37.6
2.5cm	162.7	-37.1	158.2	-34.2	-38.8	139.8	-38.5	-46.0	132.0	-38.8	-49.0
2 cm	162.3	-37.3	145.3	-39.6	-43.8	137.0	-39.8	-39.3	125.6	-41.7	-51.5

Table 1: Input impedances for different curvatures and line's width (axial case)

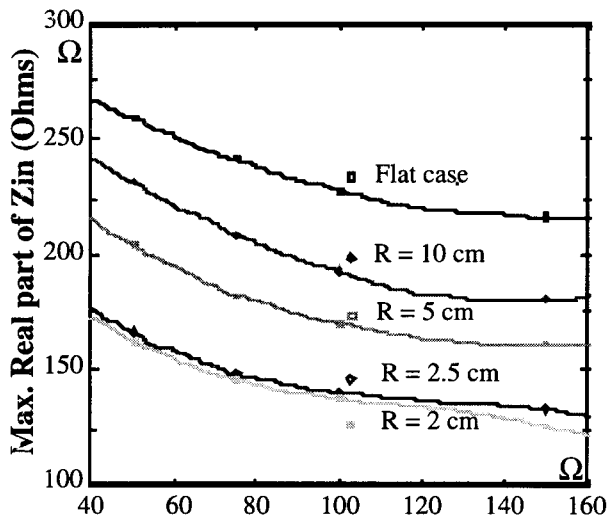


Figure 6 : Maximum of the real part of the input impedance versus  $Z_c$  for different radii.

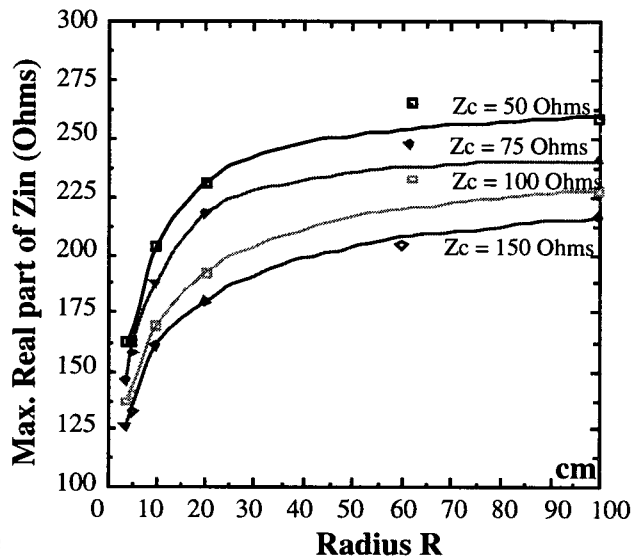


Figure 5 : Maximum of the real part of the input impedance versus the radius of curvature for different  $Z_c$

The bandwidth for different values of standard wave ratio ( $SWR < 1.5$  and  $SWR < 2$ ) are measured with the antenna matched to the maximum of the real part of the input impedance (Table 2). The positive differences in percent are calculated from the flat case for  $SWR < 1.5$  and 2. Table 2 shows that the dimension of the line doesn't modified the bandwidth, but that one of the effects of the curvature is to increase it strongly.

	$Z_c = 50 \Omega$ $W_f = 2.29 \text{ mm}$				$Z_c = 75 \Omega$ $W_f = 1.2 \text{ mm}$				$Z_c = 100 \Omega$ $W_f = 0.63 \text{ mm}$				$Z_c = 150 \Omega$ $W_f = 0.23 \text{ mm}$			
Radius	BW <1.5	Diff. %	BW <2	Diff. %	BW <1.5	Diff. %	BW <2	Diff. %	BW <1.5	Diff. %	BW <2	Diff. %	BW <1.5	Diff. %	BW <2	Diff. %
Flat	0.4	0	0.65	0	0.37	0	0.65	0	0.37	0	0.70	0	0.4	0	0.70	0
10 cm	0.45	12.5	0.75	15.4	0.43	16.2	0.80	23.0	0.45	21.6	0.85	21.4	0.45	12.5	0.85	21.4
5 cm	0.5	25.0	0.8	23.0	0.5	35.1	0.85	30.7	0.5	35.1	1.10	57.1	0.5	25.0	0.90	28.5
2.5cm	0.57	42.5	1.00	53.8	0.60	62.1	1.00	53.8	0.60	62.1	1.10	57.1	0.60	50.0	0.99	41.5
2 cm	0.63	57.5	1.05	61.5	0.65	75.7	1.10	69.2	0.65	75.7	1.15	64.3	0.65	62.5	1.10	57.1

Table 2: Influence of curvature and line width on bandwidth

## Azimuthal case

The patches fed by the different microstrip lines are now azimuthally printed on cylindrical bodies of different radii (figure 1). The results are resumed in Table 4 for the input impedance. It seems to increase when the radius decreases, however only the flat and  $R = 10$  cm cases could really be taken into account because azimuth curvatures can produce some micro slots in the feed line. We however report the measured values in table 4 for information. The bandwidths for different values of SWR ( $<1.5$  and  $<2$ ) were again measured with the antenna matched to the maximum of the real part of the input impedance but the problem is the same of the input impedance. However, for the studied cases, the bandwidths seem to be not really modified neither by the line width nor by the curvature radius. We found 0.4 % of bandwidth for SWR  $< 1.5$  and 0.65 % for SWR  $< 2$ . The small variations found are in fact due to the measurement errors.

	$Z_c = 50 \Omega$ $W_f = 2.29$ mm		$Z_c = 75 \Omega$ $W_f = 1.2$ mm			$Z_c = 100 \Omega$ $W_f = 0.63$ mm			$Z_c = 150 \Omega$ $W_f = 0.23$ mm		
Radius R	Max. Re ( $Z_{in}$ )	Diff. %	Max. Re ( $Z_{in}$ )	Diff. %	Diff. %	Max. Re ( $Z_{in}$ )	Diff. %	Diff. %	Max. Re ( $Z_{in}$ )	Diff. %	Diff. %
Flat case	258.8	0	240.6	0	-7.0	227.5	0	-12.1	215.6	0	-16.7
$R = 10$ cm	282.3	+9.1	260.9	+8.4	+0.8	233.9	+2.8	-9.6	226.0	+4.8	-12.7
$R = 5$ cm	283.6	+9.6	286.9	+19.2	+10.9	256.1	+12.6	-1.0	234.8	+8.9	-9.3
$R = 2.5$ cm	298.8	+15.5	269.8	+12.	+4.3	234.5	+3.1	-9.4	234.0	+8.5	-9.6
$R = 2$ cm	287.4	+11.0	280.1	+16.4	+8.2	290.9	+27.9	+12.4	233.9	+8.5	-9.6

Table 4: Input impedances for different curvatures and line's width (azimuthal case)

## Conclusion

An experimental study of the effects of curvature and the influence of the line feed's width on the input impedance of a microstrip antenna has been made. The results show that the input impedance strongly decreases while the bandwidth increases for an axially printed antenna on cylindrical body. This could be interesting in particular conformal applications where a larger bandwidth than the flat case is needed and could be obtained by the curvature. For an azimuthal printed patch, the curvature effects on the input impedance seems to be inverted: the input impedance seems to increase when the curvature radius increases. In this case however, some difficulties appears because the curvature tends to break the thin copper layer and particular results are obtained. Concurrently, the bandwidth is not very modified by this sense of curvature. The line's width effects were investigated too in the flat, the axial and the azimuthal case: the effects exists but are less important than the curvature effects. We can see that a small line's width seems to give a lower measured value of the input impedance. Two conclusions could be made on these experimental results. The first is that special dyadic functions or analytical expressions should be used to study printed antennas conformed on small cylindrical bodies. The second conclusion is that an attachment mode seems to be necessary to take into account the influence of the line's width. Analytical expressions could also be used.

## References

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