Master Thesis

Scanning Antenna with Rotating Septum

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Contents

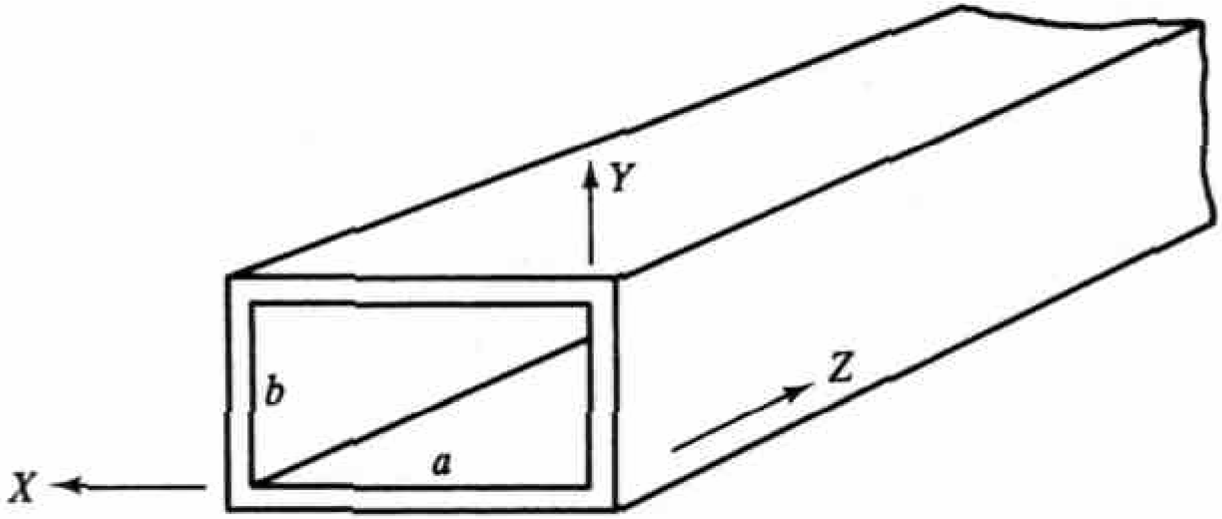
Introduction

- Very small radar sets for automobile-traffic applications have been available in the market, which monitor the road ahead, with e.g., three narrow beams from an electronically switchable multi-beam antenna.

- The operational experience with these models has shown that the monitoring angular range needs to be increased and realized with narrower antenna beams. Hence, presently, concepts are being developed worldwide to realize scanning antennas with greater angular coverage at low cost, compatible with price standards in the automobile industry.

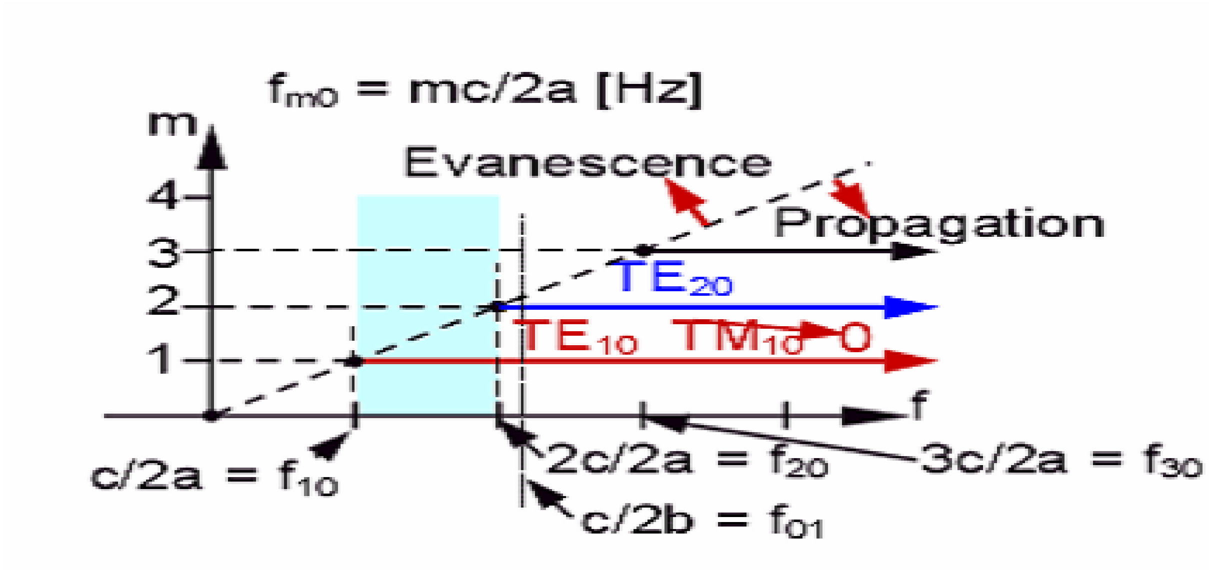
- The objective of this work is to investigate one concept, based on the principle of a mechanically fixed antenna with moving parts, in particular a rotating axis which carries a metal septum.

Slot Array Design Theory



- a is the broad dimension of guide; b the narrow dimension
- Internal dimension a = 22.86 mm and b =10.16 mm
- Cutoff at 6.56 GHz
- Use from 8.2 – 12.5 GHz

Slot Array Design Theory



$$\beta = \sqrt{k^2 - k_c^2}$$

The phase constant ß is real thus there are one or more propagating modes.

The phase constant ß is imaginary the field components decay exponentially from where they are excited. These modes are called evanescent modes.

Slot Array Design Theory

TE_{10} mode is the dominant mode in a rectangular guide and has the longest wavelength. It is by far the most important mode for antenna work.

$$k_{c10} = \frac{\pi}{a} \qquad f_{c10} = \frac{c}{2a}$$

$$\beta_{10} = \sqrt{k_0^{\,2} - \left(\frac{\pi}{a}\right)^2} \qquad \lambda_{g10} = \frac{2\pi}{\beta} = \frac{\lambda_0}{\sqrt{1 - \left(\frac{\lambda_0}{2a}\right)^2}}$$

$$\lambda_{c10} = 2a$$

Slot Array Design Theory

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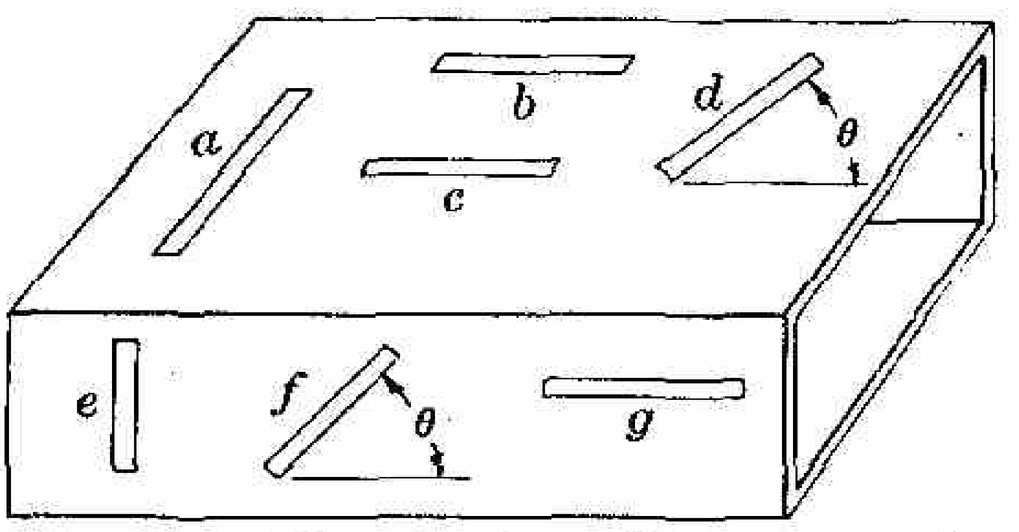
- Slots in the wall of rectangular waveguide



- The c and e are nonradiating slots because they are parallel to waveguide surface current vector
- The others are radiating slots
- The b is longitudinal shunt slot

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Slot Array Design Theory

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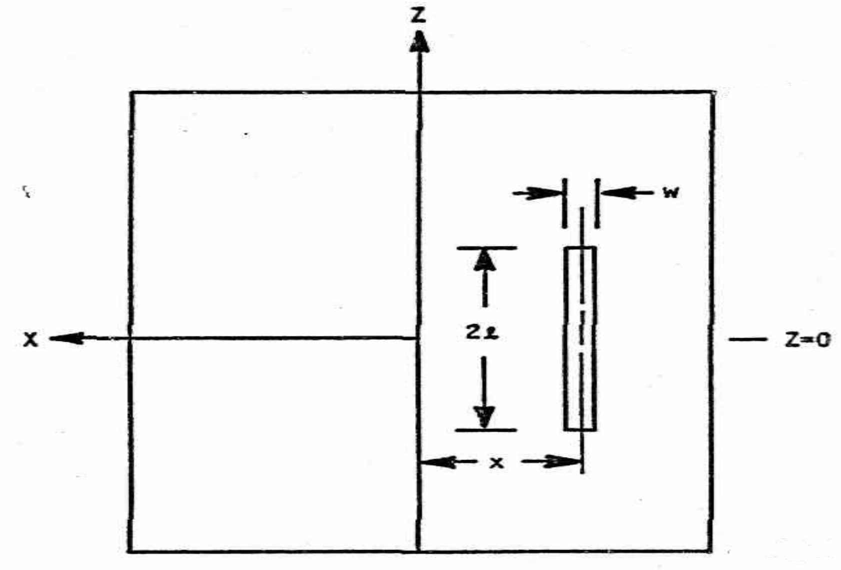
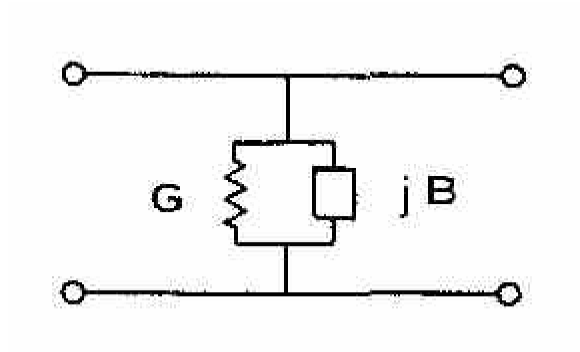


The longitudinal slot in broad wall

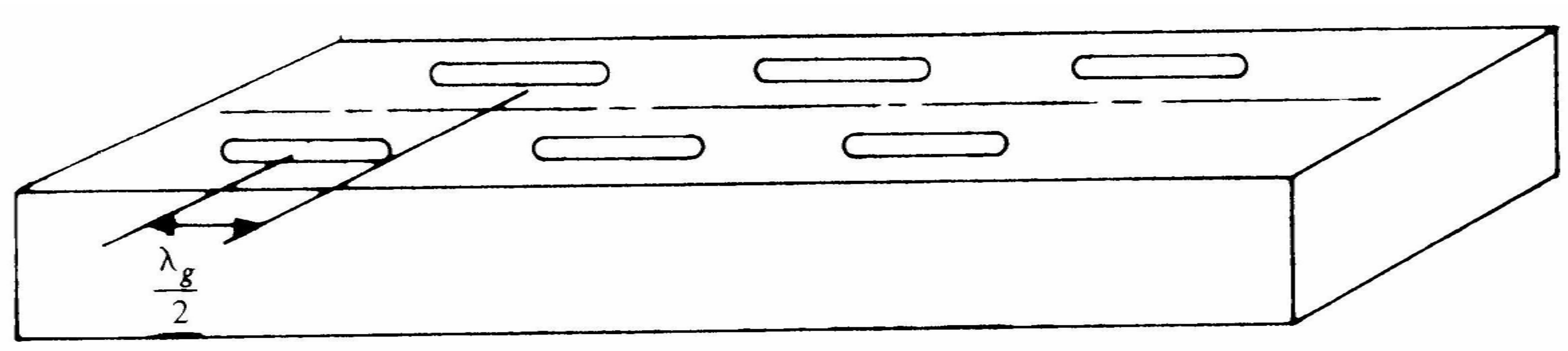


The equivalent circuit

If the slot is resonant, then the admittance of slot has no reactive component and only the conductance is left.

$$g = g_1 \sin^2\left(\frac{x\pi}{a}\right) \quad \text{and} \quad g_1 = \left(2.09\frac{a\lambda_g}{b\lambda}\right)\cos^2\left(\frac{\lambda\pi}{2\lambda_g}\right)$$

Slot Array Design Theory -Resonant Array



The resonant array is designed for broadside operation and uses a slot spacing of λg/2 .

A slot spacing of λg/2 may be used with the additional 180° change in phase between adjacent slots obtained by offsetting every other slot on the opposite side of the centerline.

The one-half guide wavelength slot spacing results in all partial reflected waves from each slot adding in phase at each slot only at the resonant frequency.

Slot Array Design Theory -Nonresonant Array

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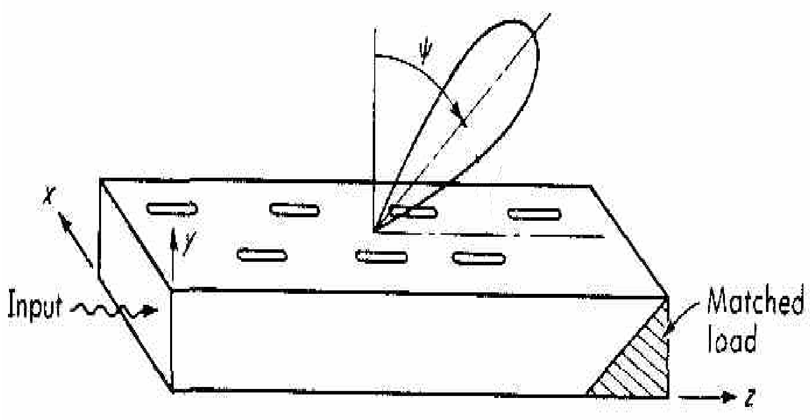
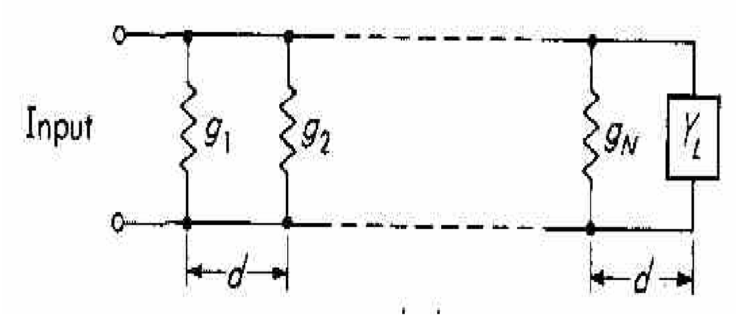
The waveguide is assumed terminated in a matched load, so the input standing-wave ratio is essentially unity in view of the small reflections produced by the individual slots and the fact that the slot spacing does not equal to λg/2, with the result that there is no in phase addition of the reflected waves.



The nonresonant array can be designed to have the main beam lobe at the any angle with respect to the normal to the broadwall of the guide.



$$\sin\Psi = \frac{\lambda_0}{\lambda_g} - \frac{\lambda_0}{2d}$$

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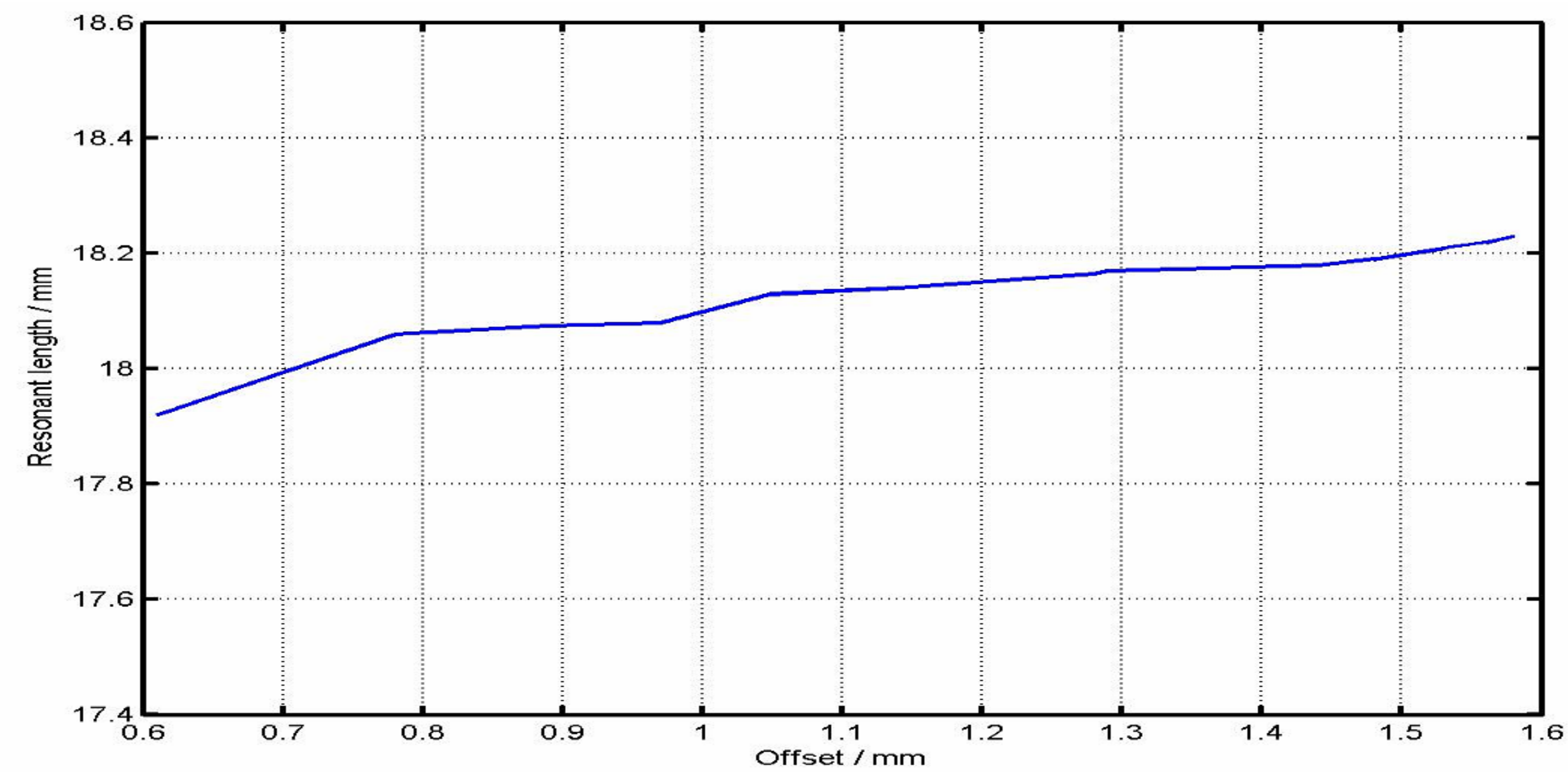
Slot Array Simulation

- The HFSS (version 5.6) has been used to model and analyze the slot array antenna.
- The resonant lengths of slots assumed approximately one-half free space wavelength.
- The selected rectangular waveguide length was 355 mm according to this length 13 slots were matched at 8 GHz.
- In order to find slots offsets and resonant lengths Villeneuve 25 dB / n = 5 distribution parameters were used.

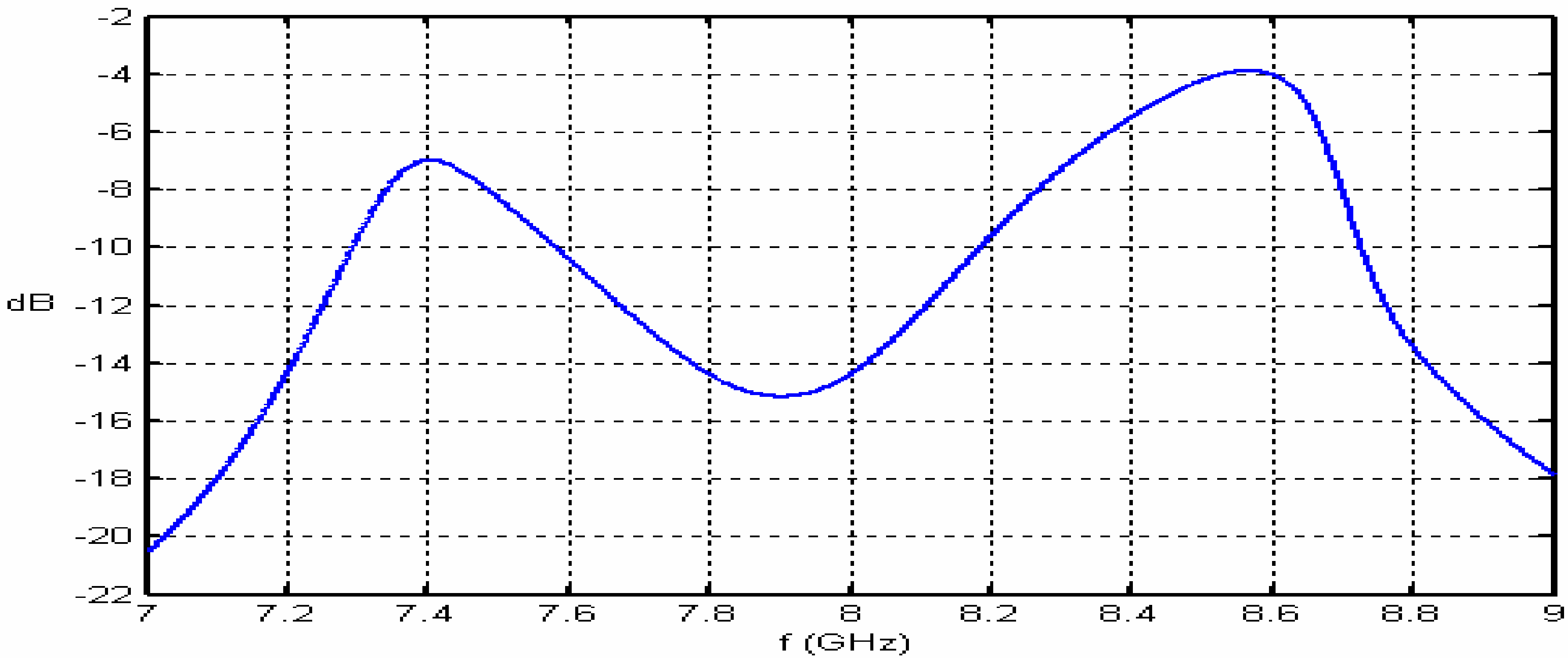
Slot array Simulation



- The resonant lengths of slots are between $0.477\lambda_0$ - $0.486\lambda_0$.

Slot Array Simulation

- Transmission coefficient, $|S_{21}|$, 13-element slot array without septum



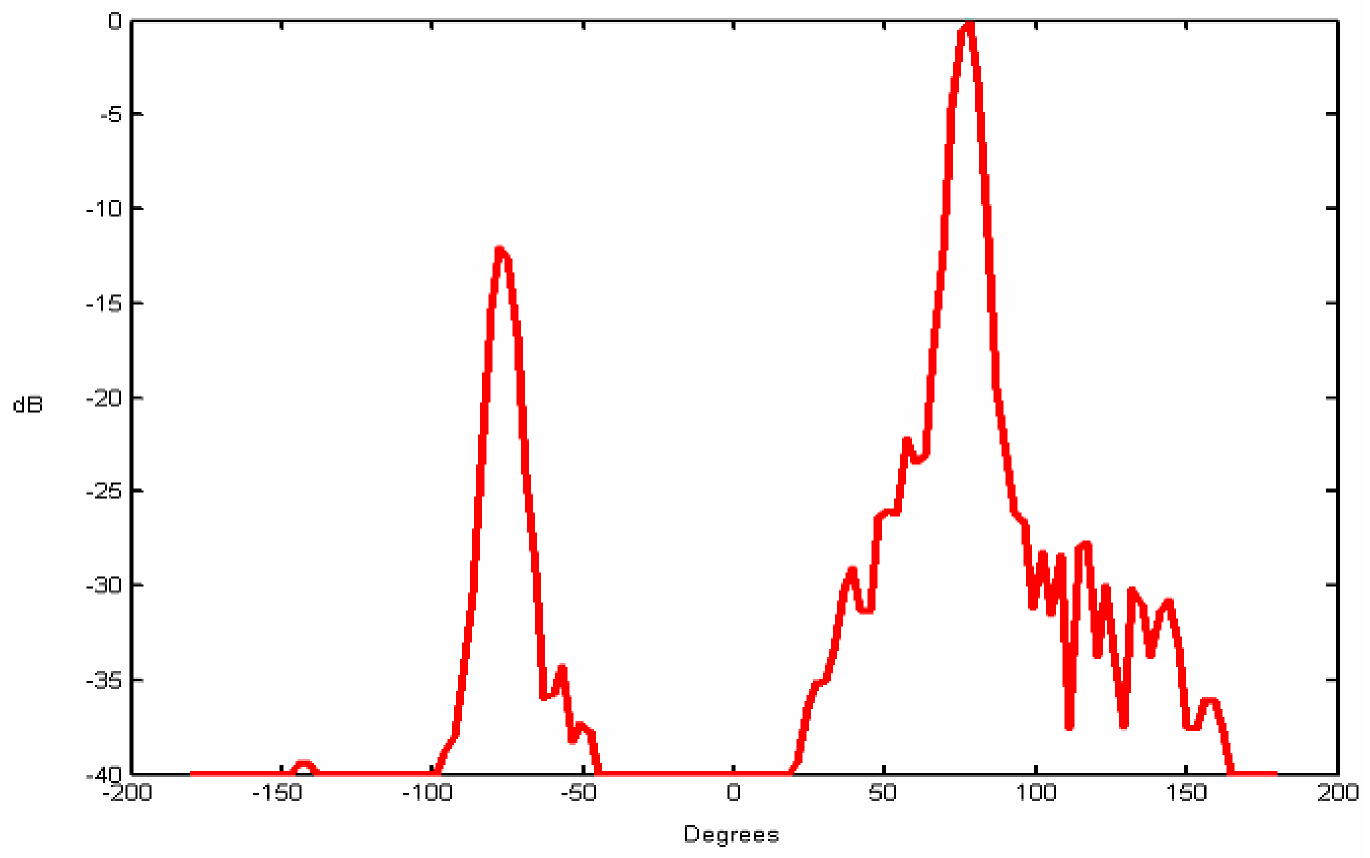
- The slot array is resonant at 7.9 GHz

Slot Array Simulation

- Radiation pattern 13-element slot array antenna

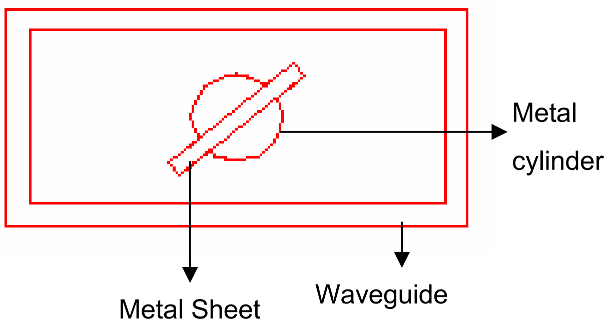
- The main beam is placed at an angle 78 degrees

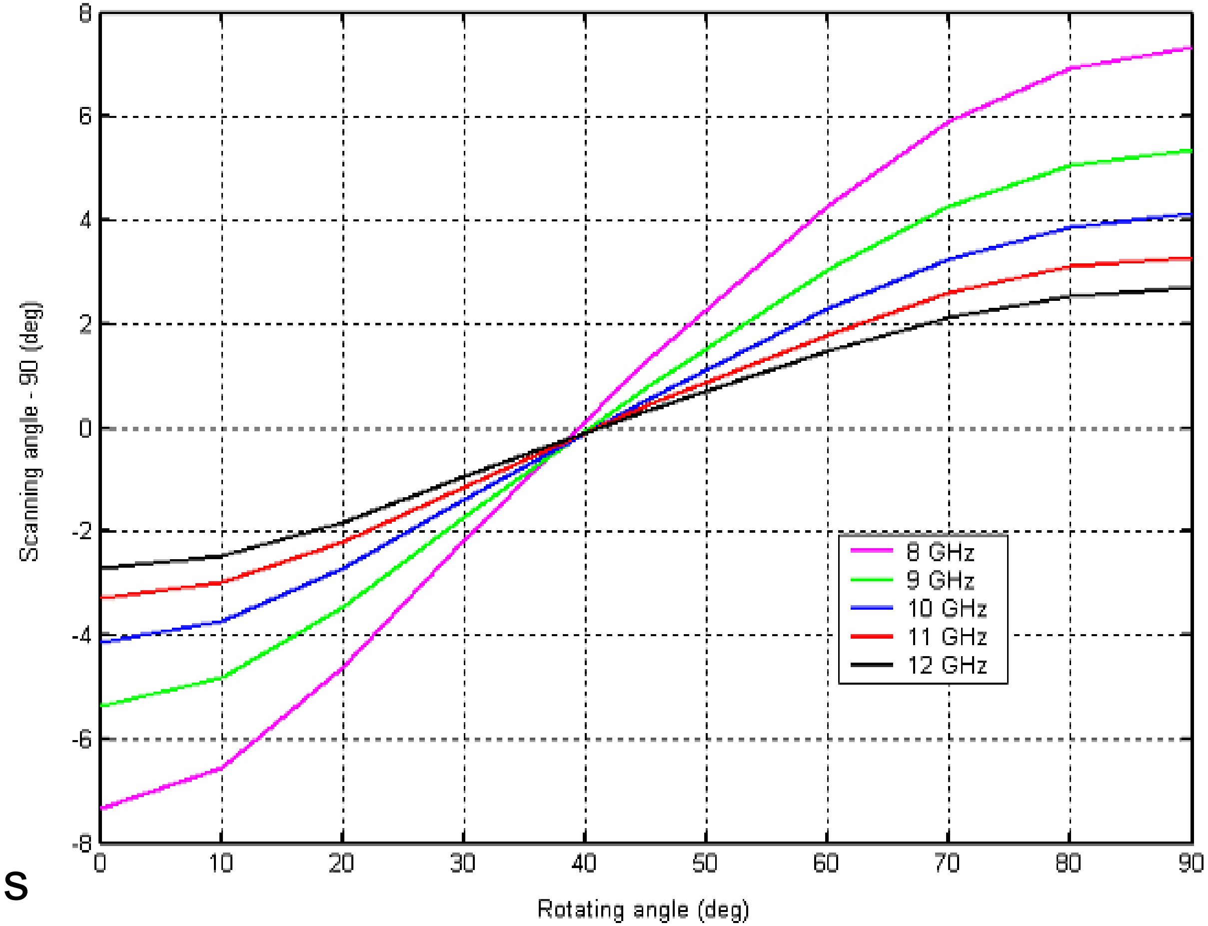
- The main beam theoretically should be placed at 77 degrees



The Rotating Septum Simulation

- Scanning angle according to metal septum position





- The Metal septum radius is 1mm
- The large dimension of rectengular metal sheet is 9mm
- The largest scanning angle is 14.66 degrees at 8 GHz

The Rotating Septum Simulation

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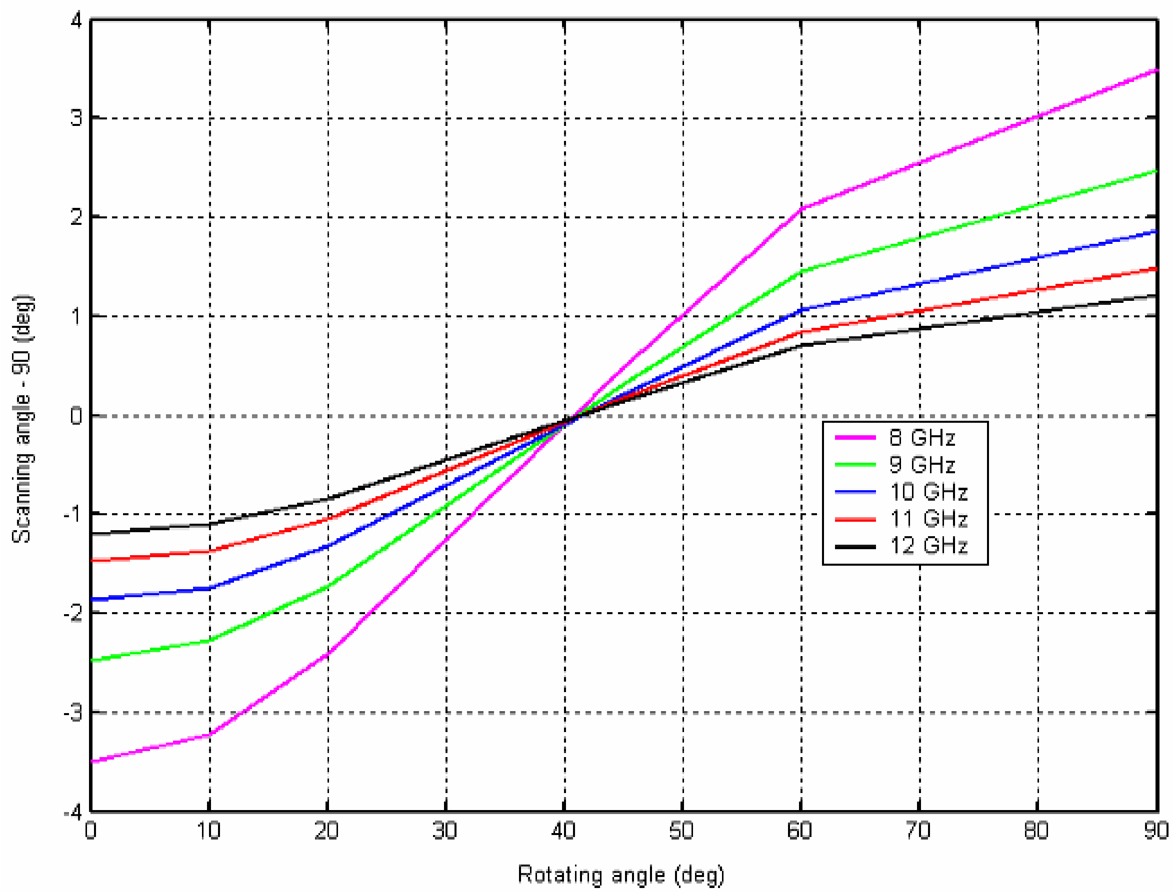
- Scanning angle according to metal septum position

• The Metal septum radius is 1mm

• The large dimension of rectengular metal sheet is 6mm

•The largest scanning angle is 6.99 degrees at 8 GHz



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The Rotating Septum Simulation

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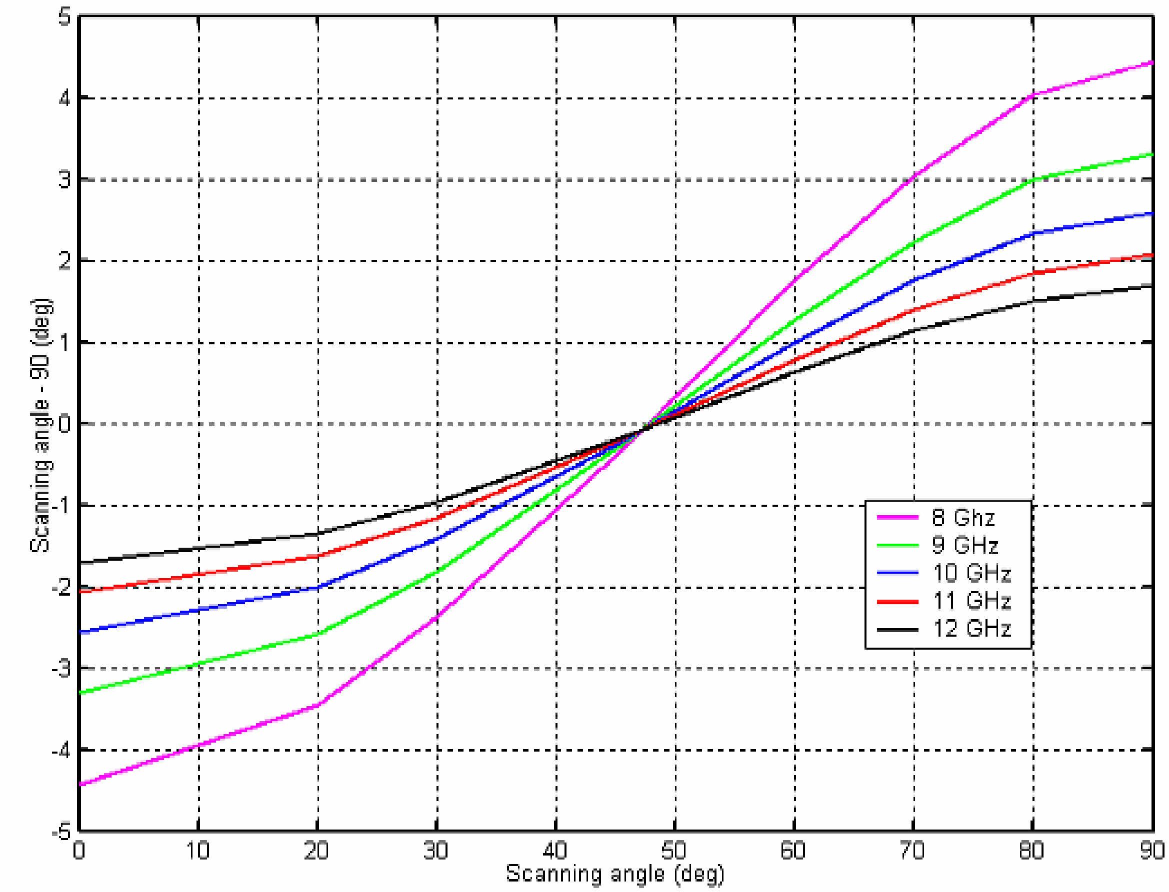
▪ Scanning angle according to metal septum position

• The Metal septum radius is 2.5mm

• The large dimension of rectengular metal sheet is 9mm

•The largest scanning angle is 8.86 degrees at 8 GHz



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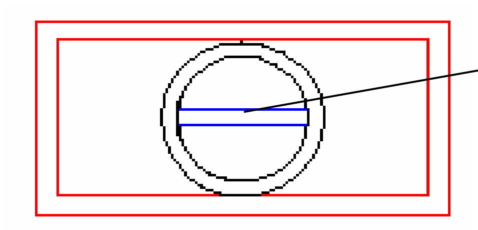
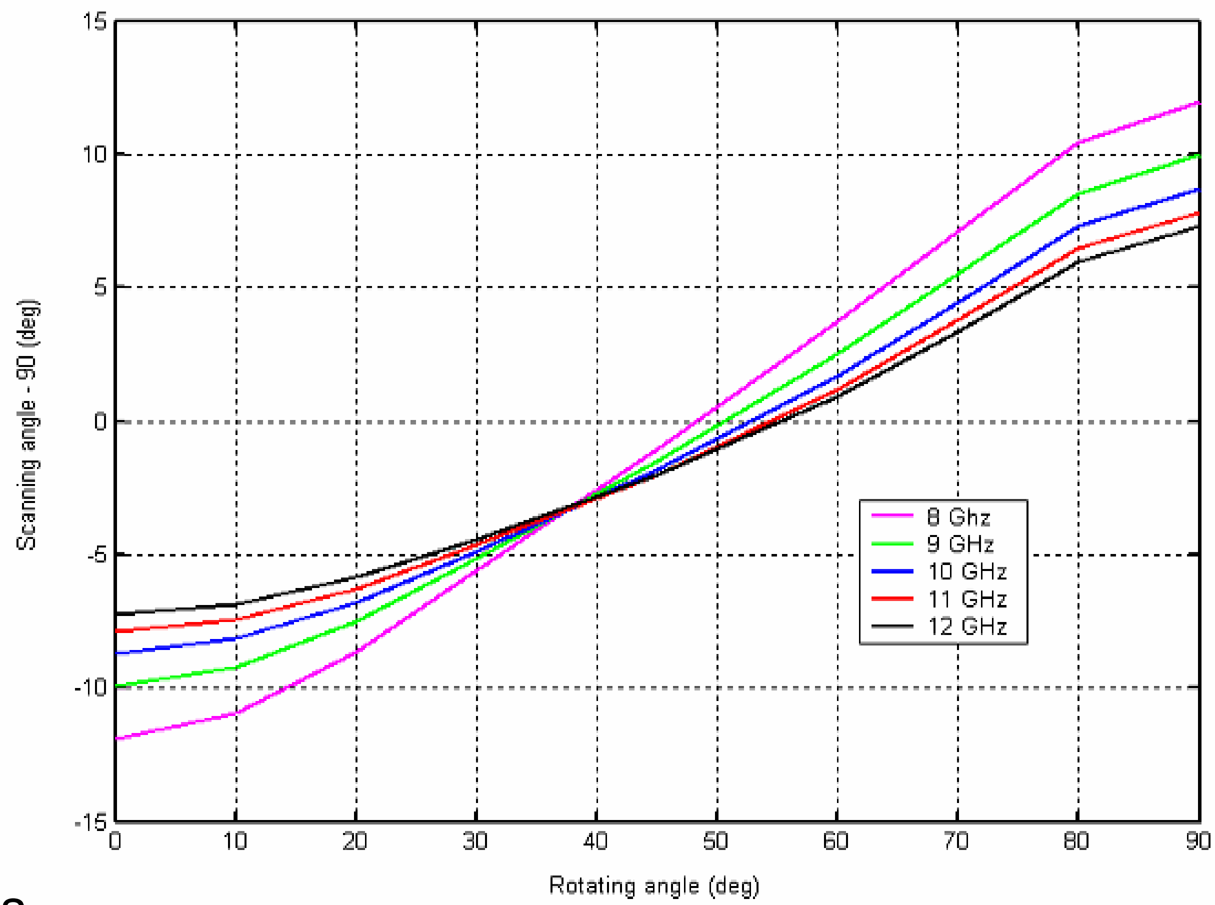
The Rotating Septum Simulation

- Scanning angle according to empty septum position.





- The empty septum radius and width are 4.5mm and 1mm
- $\varepsilon_r = 2$
- The large dimension of rectengular metal sheet is 9mm

- The largest scanning angle is 23.89 degrees at 8 GHz

The Rotating Septum Simulation

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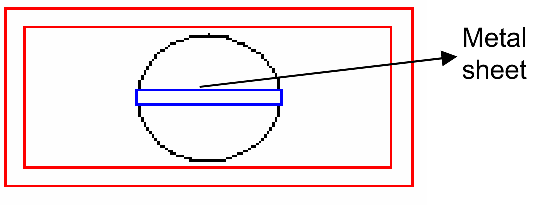
- Scanning angle according to dielectric filled septum position

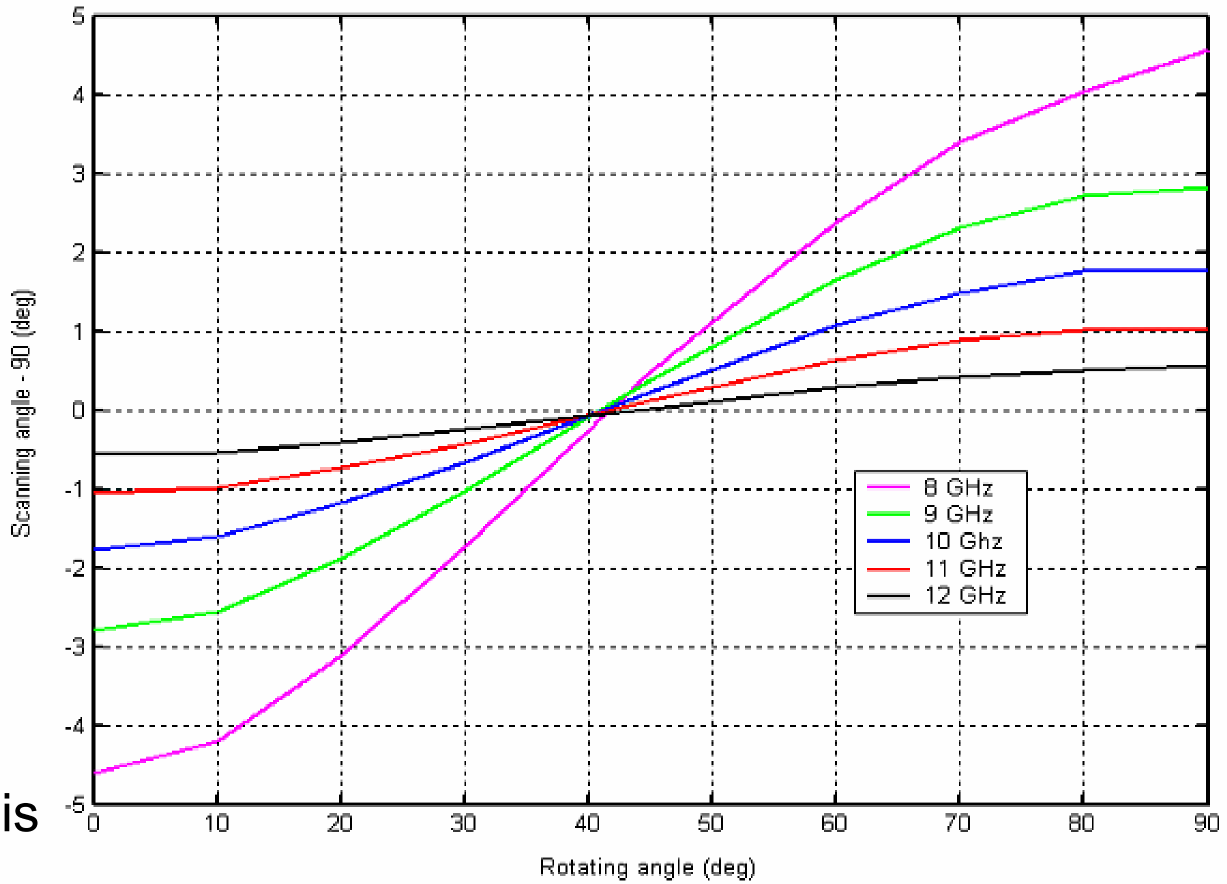


• The dielectric filled septum radius is 4.5mm

• $\varepsilon_r = 1.5$

• The large dimension of rectangular metal sheet is 9mm

•The largest scanning angle is 9.17 degrees at 8 GHz



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Experimental Results

The operating frequency was chosen 8 GHz.

The metal cylinder radius was 2.5mm.

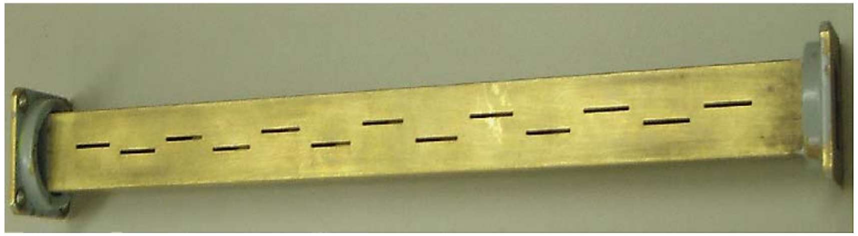
The metal sheet large dimension was 9 mm.

The slot spacing was 23.475mm

The resonant lengths of slots were simulated rectangular end but mechanically cutting slot with rectangular–end is not possible therefore the slot should be with rounded-end. Δ is correction factor

and was found 0.22

$$\Delta = \frac{L_0 - L_{\square}}{w}$$

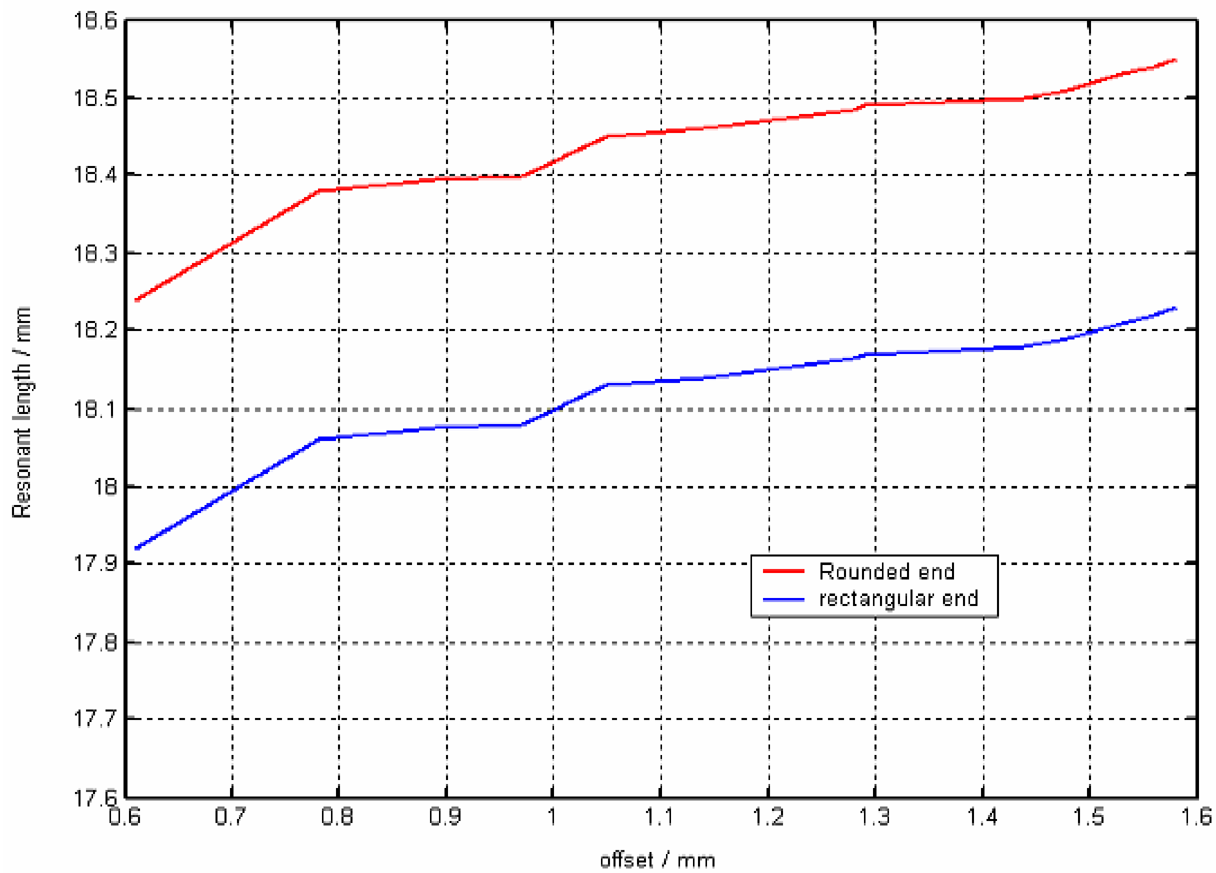


Experimental Results

▪ Comparison resonant length slot with rounded and rectangular end

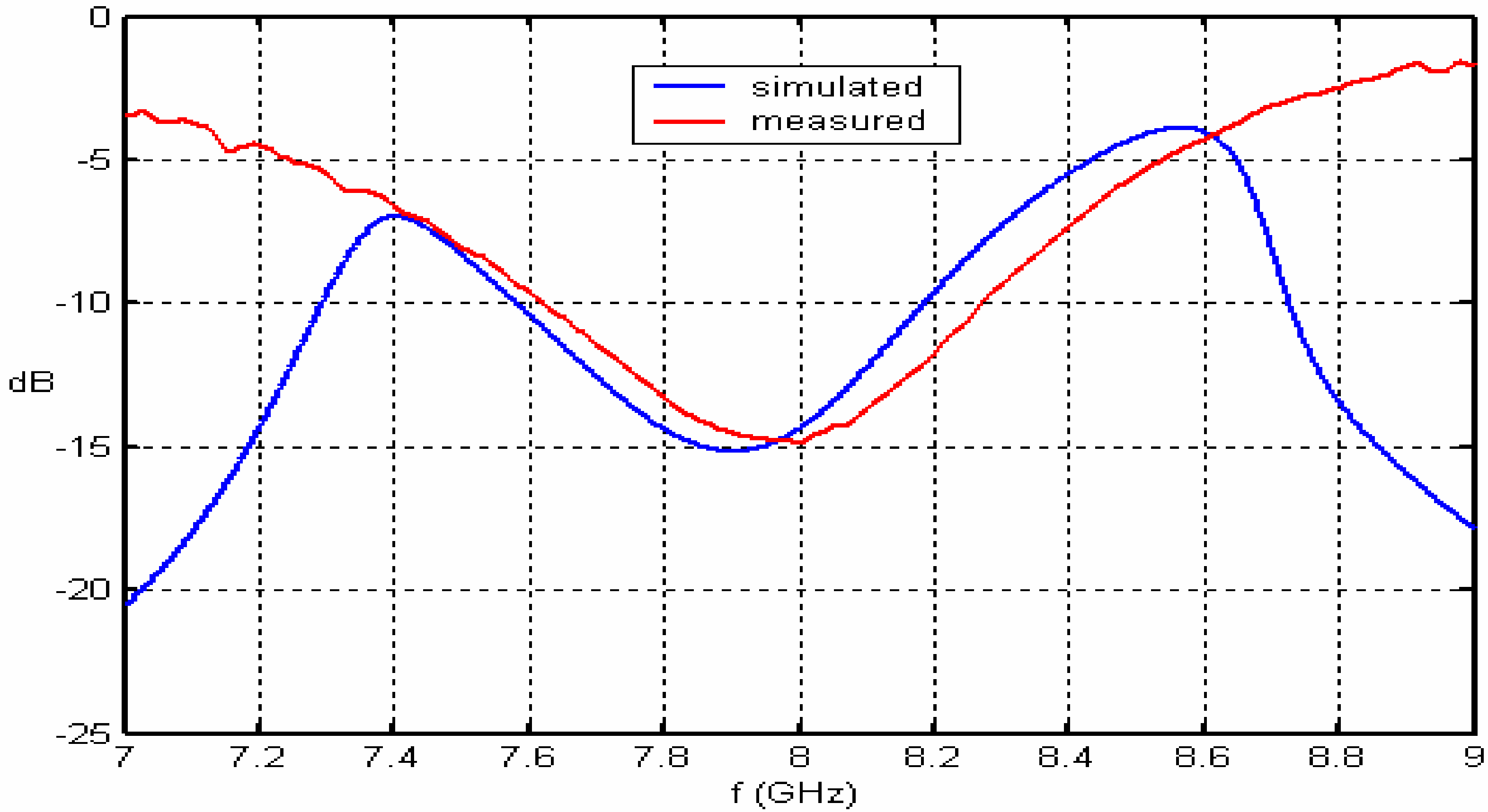
- The resonant lengths of rounded end slots are between

$0.486\,\lambda_0$ - $0.494\,\lambda_0$



Experimental Results

- Comparison of measured and simulated transmission coefficient, $|S_{21}|$,13-element slot array without septum



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Experimental Results

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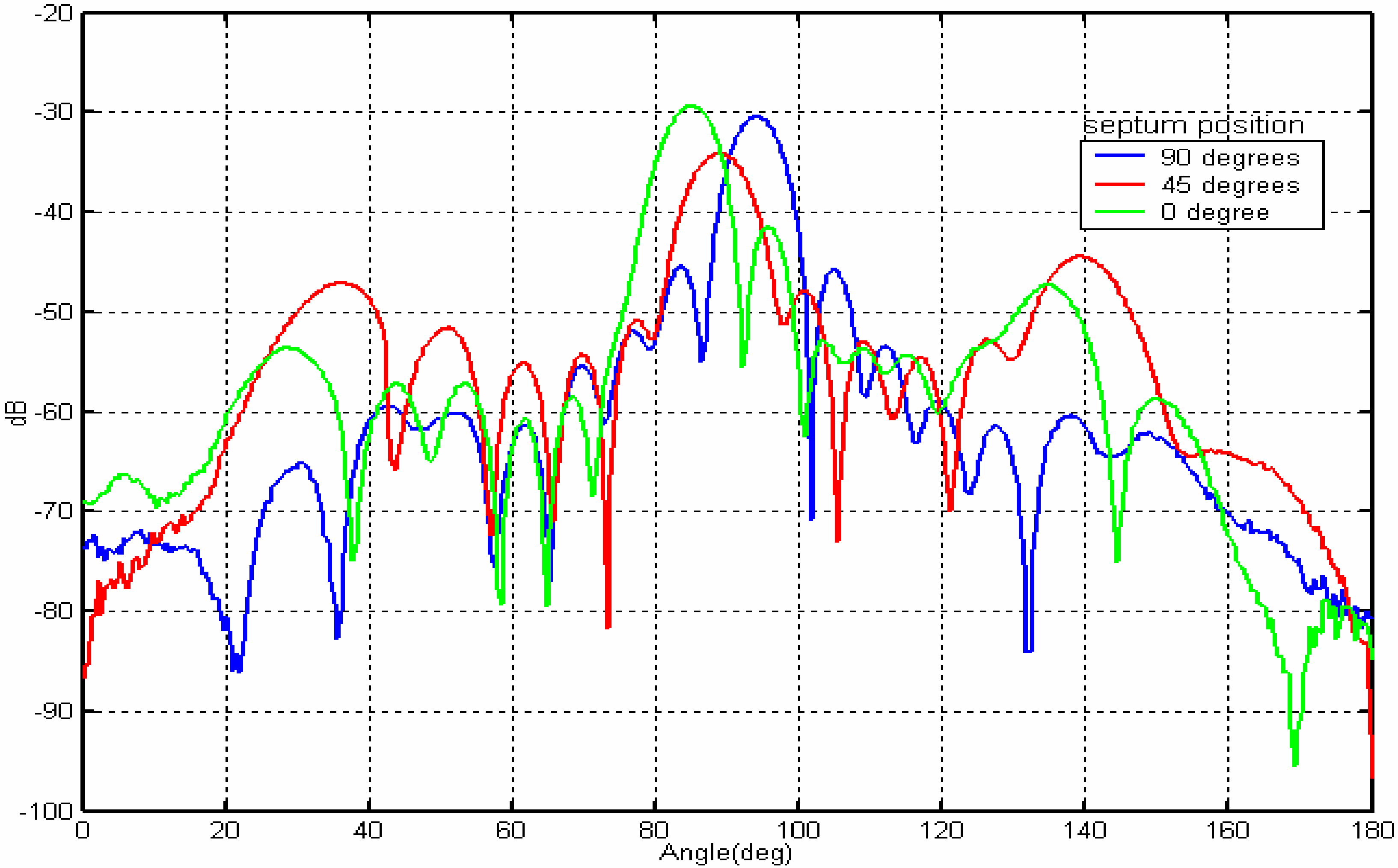
- Slot array radiation pattern with respect to septum position



Experimental Results

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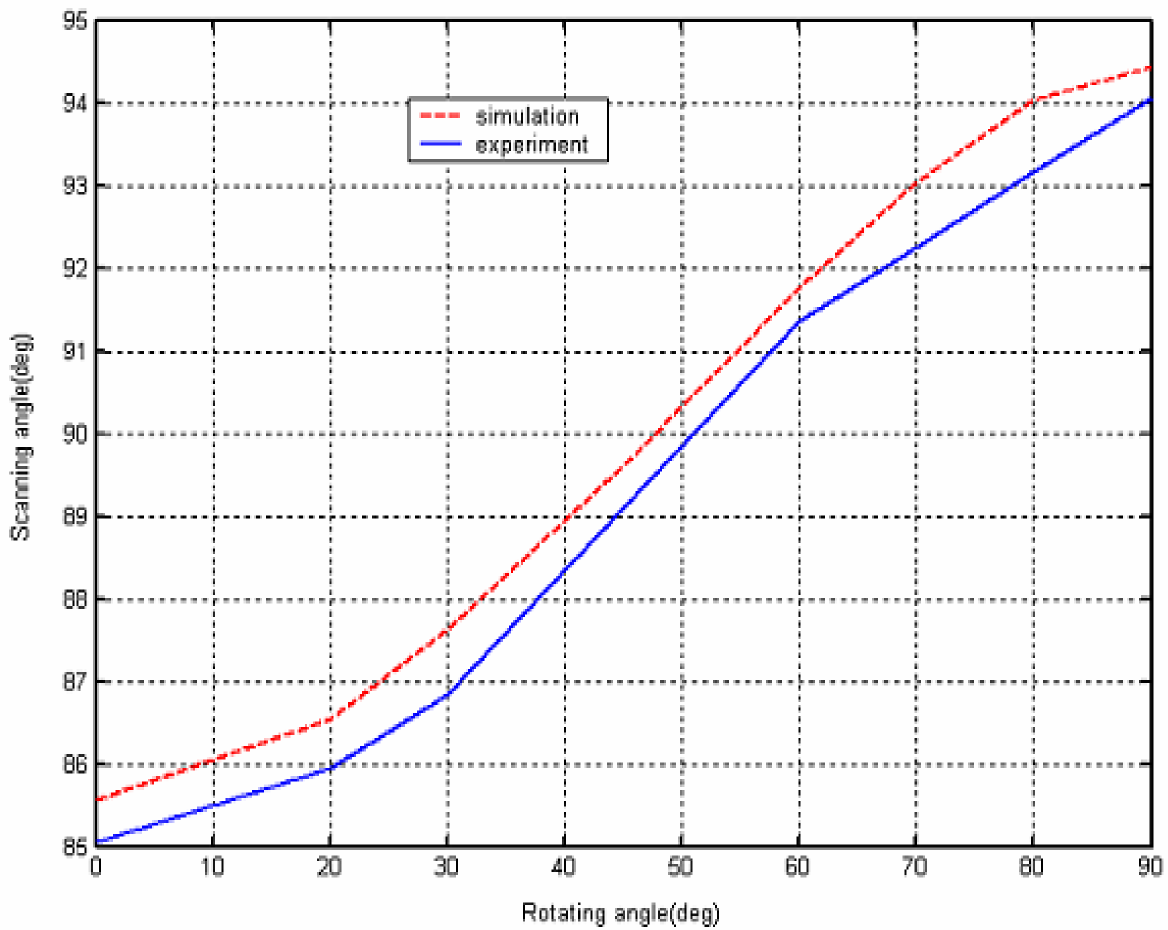
- The scanning angle

• The main beam is scanned 8.86 degrees, from 85.57 to 94.43, in the simulation.

• The main beam is scanned 9 degrees, from 85.05 to 94.05 , in the experiment.



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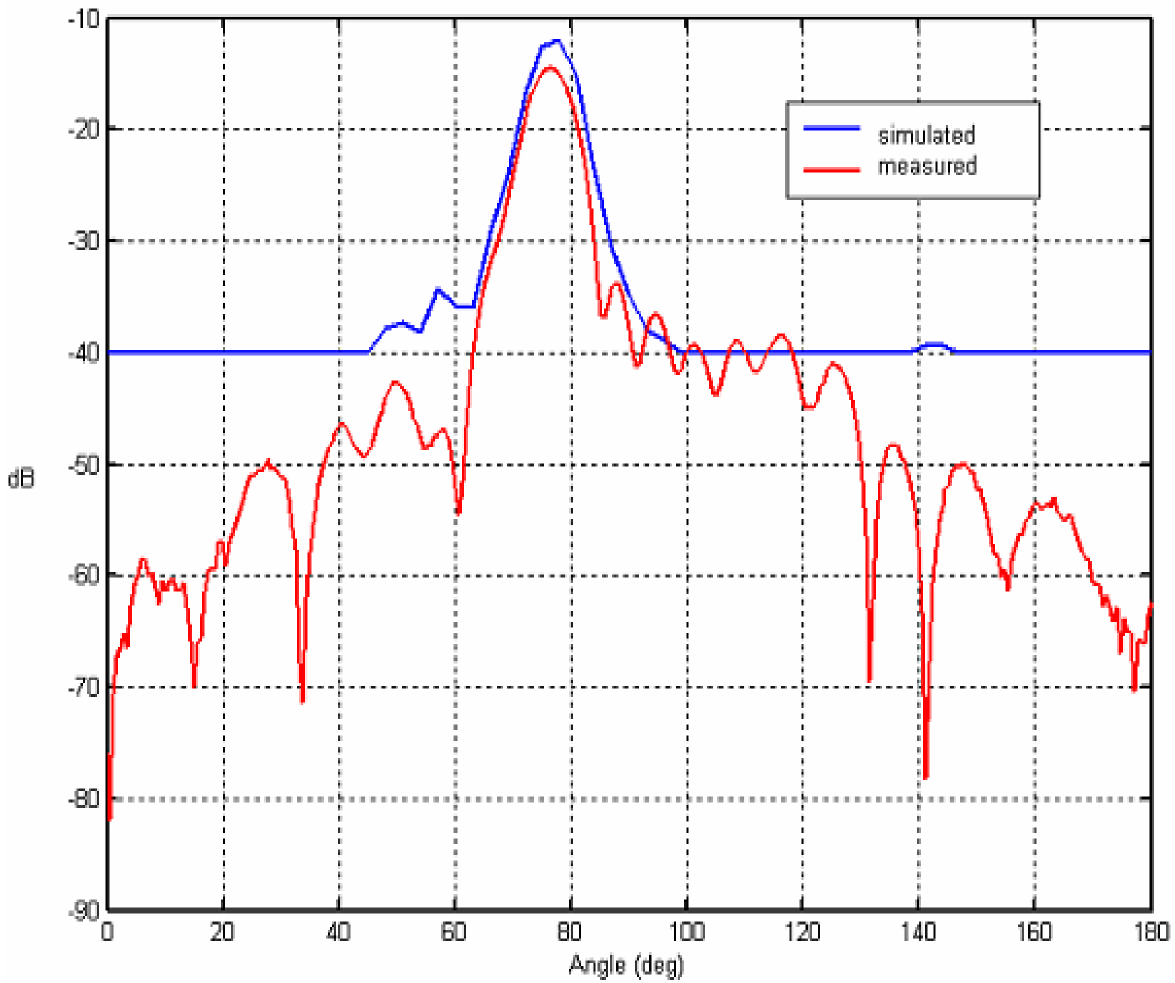
Experimental Results

- The main beam is placed in experiment at 76.8 degrees.

- The main beam is placed in simulation at 78 degrees.



Conclusion

- In this work, it was shown that the scanning angle depends on the septum parameters that are septum radius, metal sheet dimension, septum material type and operating frequency
- The slotted array parameters were found
- One of the septum parameter combinations has been chosen for the experiment
- The scanning angle was found 9 degrees

Thank you for your attention