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GAIN & BANDWIDTH ENHANCEMENT OF ANTENNA USING NUMERICAL EXPERIMENTATION

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Abstract
This paper covers important aspect of microwave communication technology. The vehicular satellite communication and automotive radar applications require light- weighted and low cost antennas with possibility of conformal integration. The microstrip antenna is a good choice. However, they have typical gain of about 6-7 dBi only. This paper describes the analysis and design of new wideband high gain microstrip antennas with the concept of the short surface mounted horn to increase the gain and bandwidth. The numerical simulation is done with the help of 3D- EM SIMULATOR, Microwave Studio.

Introduction
The function of an antenna is to convert an RF signal from a transmitter to a propagating electromagnetic wave or conversely convert a propagating wave to an RF signal in a receiver [1].In this brief introduction we describe the basic RF stages of wireless transmitters and receivers, and provide an introductory discussion of the main RF and microwave components as shown in Fig. 1.

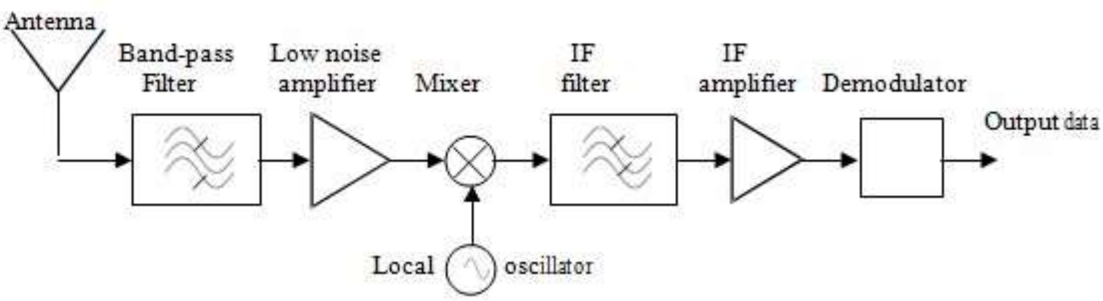

Figure1.Block diagram of a basic radio receiver

Planar oriented antennas, such as microstrip patch and printed dipole have offered tremendous benefits to modern wireless systems in comparison to more conventional designs. The microstrip antenna has following advantage

1. Low profile;
2. Lightweight antennas;
3. Most suitable for aerospace and mobile applications;
4. Easily integrated with electronic components;
5. Easily integrated into arrays.

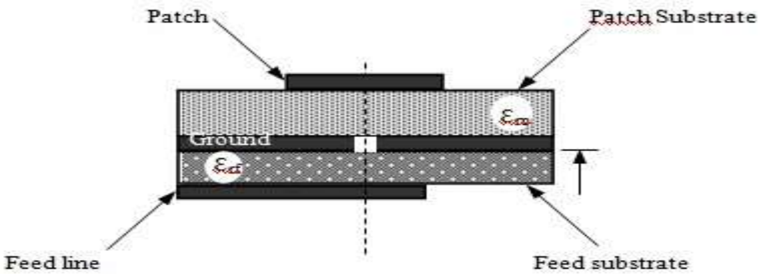

Figure2.Microstrip patch antenna

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As customers demand smarter, smaller lower cost products, more innovative antennas will be required. Microstrip antennas are ideal for these applications are shown in figure 2. They are very thin. They are compatible with IC technology in the sense that they readily interface with IC interconnects. They can even be made part of the chip. Most importantly, microstrip antennas are manufactured with printed circuit techniques and, therefore, are very low in cost.
The some important parameter in antenna analysis is the input impedance, or equivalently the input return loss, which describes how well the antenna, is matched with its feeding network. The impedance bandwidth is another important parameter. As wireless communication applications require more and more bandwidth such as high data rate communication systems, the demand for wideband antenna increases as well. One of the major disadvantages of microstrip antennas is their inherent narrow bandwidth. The narrow impedance bandwidth is ultimately a consequence of its electrically thin ground- plane- backed dielectric substrate, which leads to a high-resonance behavior. Bandwidth improves as the substrate thickness is increased. A thick substrate will support surface waves, which will deteriorate the radiation patterns as well as reduce the radiation efficiency. Here [4] we introduced a wide bandwidth aperture coupled microstrip antenna. By choosing the suitable substrates relative permittivity and thickness, a bandwidth of 12.4 % has been obtained from a simple aperture coupled microstrip antenna.
For many applications such as satellite communications and mobile radio, for which printed antennas are otherwise well-suited, low gain may be a serious disadvantage. The electromagnetically coupled stacked patch antenna has been investigated to improve the gain and bandwidth the microstrip antenna. We have introduced the short surface mounted horn to increase the gain and bandwidth of the patch antenna [6]. This new combination of the aperture coupled microstrip antenna and the quasi-planar surface mounted short horn is demonstrated to increase the gain of the patch antenna. A systematic numerical experimentation on a 3- D EM simulator, Microwave Studio [11] is presented to achieve high directivity.

Numerical experimentation

This section introduces a new probe fed microstrip antenna element with the quasi-planar surface mount short horn. The proposed new structure is shown in Fig. 3. In the present arrangement, the aperture coupled rectangular patch is not the main radiating element. It is a feed to the short surface mounted horn antenna. The maximum directive gain depends on the relative permittivity and thickness of substrate of the patch, operating frequency, separation distance, d of the horn from the edge of the patch and the slant – angle, θ_s of the horn. Using a longer horn can also increase the gain. However, the structure will not be quasi-planar. At first, we have attempted to optimize size of a quasi-planar short horn and its placement with respect to the patch in order to obtain the maximum possible gain for the compact structure. A probe-fed square microstrip antenna, with dimension, 0.857cmx0.857cm is designed on a square dielectric substrate of size, 8.0 cm x 8.0 cm x 0.081cm and relative dielectric constant ε_r = 4.38. The patch antenna resonates at 8.77 GHz. A short horn of slant length, $L_S = \lambda_o/4$ = 0.875 cm is selected in this work. λ_o is the wavelength at the resonance frequency.
The total distance between center of the patch and inner edge of the horn is, $D = L_p + d$.
Where $2L_p$ is the dimension of square patch and d is the distance between edge of the patch and inner edge of the horn. The slant length of horn makes θ ° angle with respect to the vertical axis to the patch. Through numerical experimentation we optimize horn position, d and slant angle θ ° to achieve the maximum gain. For several horn position, d between $\lambda_o/16$ to λ_o, we compute broadside directivity of the patch radiator at slant angles between $\theta° = 0°$ and $90°$ with help the 3D- EM simulator, Microwave Studio [11].

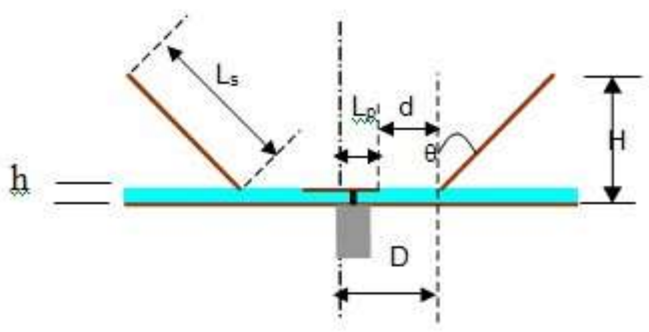

Figure3.Microstrip patch antenna with quasi-planar surface mounted horn

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Measurement and results

A microstrip antenna on the thin substrate provides narrow bandwidth, typically about 2%. Therefore, we examined the microstrip antenna with and without horn on the thick substrates also. The numerical investigation is carried out for the quasi-planar horn of slant length, $L_S = \lambda_o/4$, slant angle, $\theta = 60°$ and horn position, $d = \lambda_o/8$ and $\lambda_o/4$. The thickness of substrate, h is 0.081 cm and thick substrates are taken in multiple of this basic thickness. The results of numerical investigation are shown in Table 1.1

Directivity and bandwidth measurement

From the table it shows that for the horn position, $d = \lambda_o/8$, directivity of the antenna with horn decreases from 10.7 dBi to 7.8 dBi with the increase in the substrate thickness from h to 4h. The degradation in directivity of the patch antenna with horn is due to leakage of power from the thick radiating aperture of the patch. The leaked power does not reach to the horn for sufficient radiation. Table 1 .1 further shows that for the horn position, $d = \lambda_o/4$ the directivity is increased to 11 dBi. The enlarged dimension, d of base of the horn helps to collect more power to the horn.

Table 1.1 further shows that with increase in thickness of the substrate from h to 4h, the bandwidth of the patch radiator increases from 2.67 % to 11.8%. For the horn placed at $d =\lambda_o/8$, the bandwidth is reduced a little. However, it increases from 2.30 % to 11.6 % with increase in substrate thickness from h to 4h.The bandwidth shows improvement for the horn position, $d = \lambda_o/4$. Table 1 .1 shows that the feed position for the proper matching changes with thickness of the substrate and also by presence of the horn. This should be taken care of to design the microstrip antenna with surface mounted qausi-planar horn.

Table 1 .1 Simulated results Microstrip patch antenna with quasi-planar surface mounted horn for slant angle $\theta = 60°$ and $L_S = \lambda_o/4$

Substrate thickness (h=0.081cm)	Directivity without horn (dBi)	Directivity with ho d=$\lambda_o/8$ (dBi)	Directivity with hor d=$\lambda_o/4$ (dBi)	Band-Width No horn	Band-Width with hor d=$\lambda_o/8$	Band-Width with horn d=$\lambda_o/4$	Feed position without horn	Feed position with horn d=$\lambda_o/8$	Feed position with horn d=$\lambda_o/4$
1	6.27	10.7	10.1	2.67%	2.3%	2.63%	0.12	0.105	0.115
2	6.47	10.5	11.0	6.58%	4.48%	5.58%	0.17	0.14	0.150
3	6.70	9.70	11.0	10.5%	7.82%	9.2%	0.27	0.23	0.250
4	6.90	7.80	10.7	11.8%	11.6%	10.93%	0.40	0.39	0. 400

Gain and return loss measurement

The measured result validates the simulation results [10]. We make a detail comparison between the measured performance and the simulation of the patch antenna, with and without horn in the Table 1.2. We obtain 9.0 dBi gains as compared to the standard horn. The Table 1.2 also shows an improvement of 3.5 dB gain by use of the quasi-planar horn.

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Table 1 .2Experimental and Simulated Performance of Probe-fed Microstrip Antenna with and without Horn

Parameter		With horn		Without horn	
		Experiment	Simulation	Experiment	Simulation
h = 0.081 cm	S_{11}(db)	-35	-40	-22	-25
	Gain	9 dB	10 dB	5.5 dB	6 dB
h = 0.243 cm	S_{11}(db)	-40	-45	-30	-32
	Gain	11.5 dB	12 dB	8.5 dB	9 dB

As shown in Fig. 4.the horn has improved the return loss from –22 dB to –35 dB. Similar results are obtained for the patch on thicker substrate, h=0.243 cm. For this case we obtained 11.5 dBi gains with horn. Details are shown in the table 1.2. We obtained11.5 dBi gain with thicker substrate with horn and 8.5 dBi gain without horn with the help of a standard horn.

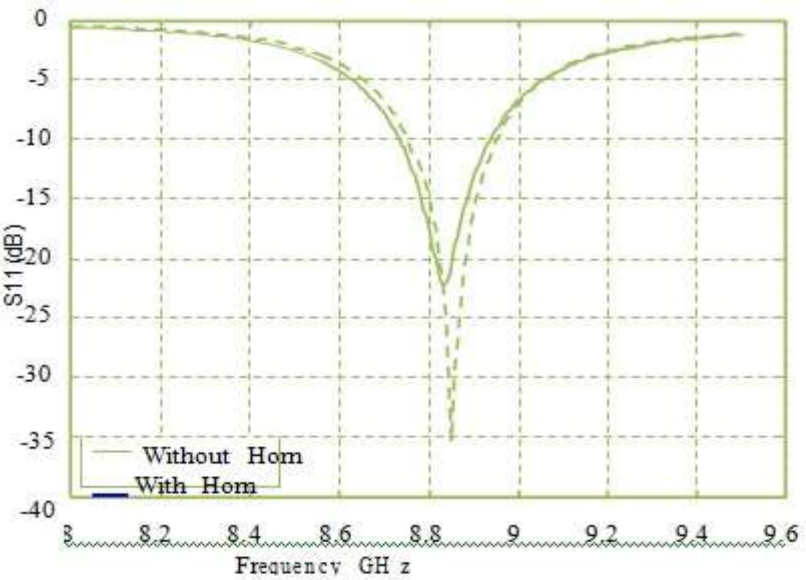

Figure4 Measurement of return-loss with and without horn

Conclusion

We have introduced in this paper a new combination of the aperture coupled microstrip antenna and a quasi-planner surface mounted short horn to increase the gain and bandwidth of the patch antenna and do its validation using 3D-EM SIMULATOR. By choosing the suitable substrates relative permittivity and thickness, a bandwidth of 11.6 % has been obtained from a simple, low profile, and light weight aperture coupled Microstrip antenna. As some of the power leaks through the substrate as a surface waves. To trap and guide this leaked power to the broadside direction, the surface mounted horn is used on the substrate and by increasing the substrate thickness the gain of the patch antenna has been increased by more than 11 dB.

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