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U-Shaped Rectangular Patch Microstrip Antenna Element For Base Station Antennas

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Abstract: - In this paper, a new design for microstrip antenna element with U-shaped rectangular patch for sectored coverage of base station antennas of 900 MHz system is proposed for improving antenna performance in terms of gain and bandwidth. A superstrate or dielectric cover is used to protect the patch against environmental hazard. We have present also another solution using air dielectric as a superstrate, which is a much lighter and cheaper solution A green's function based mixed potential integral equation in conjuction with the method of moments is implemented for the formulation and analysis of the microstrip structures. For this contribution, design aspects and the obtained simulated results for the proposed antenna are presented.

1 Basic Formulations:

For an simple region as in Fig.1. the current in radiating elements and feeding elements is expanded into a set of

basis functions : $\vec{J} \approx \sum_{j=1}^{N} C_j J_j$, (1)

Where J_j are the basis functions and C_j corresponding coefficients.

In case that the simple region is connect to the outside through aperture coupling, the field in apertures is expanded into basis functions:

$$\vec{E} \approx \sum_{k=1}^{M} \gamma_k \vec{E}_k \tag{2}$$

Thus, the magnetic current excitation over the apertures is expressed by :

$$\vec{M}_a \approx \sum \gamma_k \vec{M}_k \text{,where: } \begin{array}{l} \vec{M}_a = \vec{E}_a x \vec{n} \\ \vec{M}_k = \vec{E}_k x \vec{n} \end{array} \tag{3}$$

If all metal sheets are perfect conducts, tangential electric field will vanish on all metallic surfaces inside the region, so :

$$\vec{E}(\vec{J}) + \vec{E}(\vec{M}_a) = 0 \tag{4}$$

If the metal sheets are not perfect conducts, we have to apply the impedance boundary conditions:

$$\vec{E}(\vec{J}) + \vec{E}(\vec{M}_a) = Z_s \vec{J} \tag{5}$$

Z_s is the impedance surface(Ω / square meter).

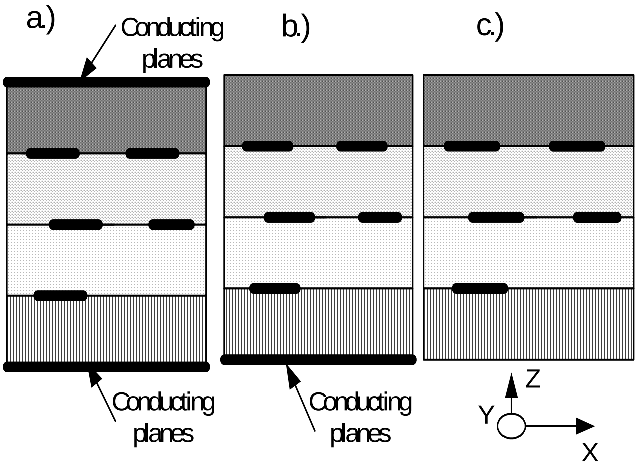


Fig. 1 Simple region. Conducting patches embedded in multiplayer dielectric media bounded by a.) two conducting plane b.) one conducting plane c.) no conducting boundaries other than the patches.

In specific case of rectangular microstrip antennas with a coaxial feed (Fig.2) total current on the patch and probe is expanded into:

$$\vec{J}_s = \sum_{n=1}^{N} a_n \vec{f}_{patch,n} + \sum_{m=1}^{M} C_m f_{zm}\hat{z} + d\,\vec{f}_{atta} \qquad (6)$$

$\vec{f}_{patch,n}$ - Basis function on the patch, f_{zm} - basis functions on the probe, and f_{atta} - special basis functions to ensure the continuity of current at the patch – probe junction. The field inside coaxial cable can be expressed as:

$$\vec{E}_{z\le z_g} = \vec{E}_0(\vec{r}_s)e^{-jk_0(z-z_g)} + \sum_{l=1}^{L-1}\Gamma_l \vec{E}_l(\vec{r}_s)e^{-jk_{lz}(z-z_g)} \qquad (7)$$

$$\vec{H}_{z\le z_g} = \vec{H}_0(\vec{r}_s)e^{-jk_0(z-z_g)} + \sum_{l=1}^{L-1}\Gamma_l \vec{H}_l(\vec{r}_s)e^{-jk_{lz}(z-z_g)} \qquad (8)$$

$\vec{E}_0$ *and* $\vec{H}_0$ the fields of TEM mode, $\vec{E}_l$ *and* $\vec{H}_l$ ($l > 0$) , are the fields of higher modes.
$\vec{r}_s = x\hat{x} + y\hat{y} + z\hat{z}$, $\vec{r}_s = x\hat{x} + y\hat{y}$, where z_g is the z- coordinate of the ground plane which we take as a reference point.

The field on aperture ($z=z_g$) is:

$$\vec{E}_a = \vec{E}_0(\vec{r}_s) + \sum_{l=1}^{L-1}\Gamma_l \vec{E}_l(\vec{r}_s) \qquad (9)$$

$$\vec{H}_a = \vec{H}_0(\vec{r}_s) + \sum_{l=1}^{L-1}\Gamma_l \vec{H}_l(\vec{r}_s) \qquad (10)$$

If $\vec{E}_0, \vec{H}_0$ are the known incident field and using (4) and (5) it is possible to solve equations for the unknown coefficients.
The input impedance Z_{in} of the antenna is

$$Z_{in} = Z_0\frac{1+\Gamma_0}{1-\Gamma_0}, \qquad (11)$$

$\Gamma_0 - reflection\ \ coefficient$

$Z_0 - Characteristic\ impedance\ of\ the\ coaxial\ cable$

If only the TEM mode is used (while coaxial cable is smaller than the dimension of the patch)
The input impedance will be (for detail see lit. [8]):

$$Y_{in} = \frac{1}{Z_{in}} = \frac{\sum_{n=1}^{N} a_n\left\langle \vec{f}_{patch,n}, \vec{M}_0\right\rangle + \sum_{m=1}^{M} a_n\left\langle f_{zm}\hat{z}, \vec{M}_0\right\rangle + d\left\langle \vec{f}_{atta}, \vec{M}_0\right\rangle + b_0\left\langle \vec{M}_0, \vec{M}_0\right\rangle}{b_0\left\langle \vec{H}_0, \vec{M}_0\right\rangle}$$

$, b_0 = 1+\Gamma_0$

$$(12)$$

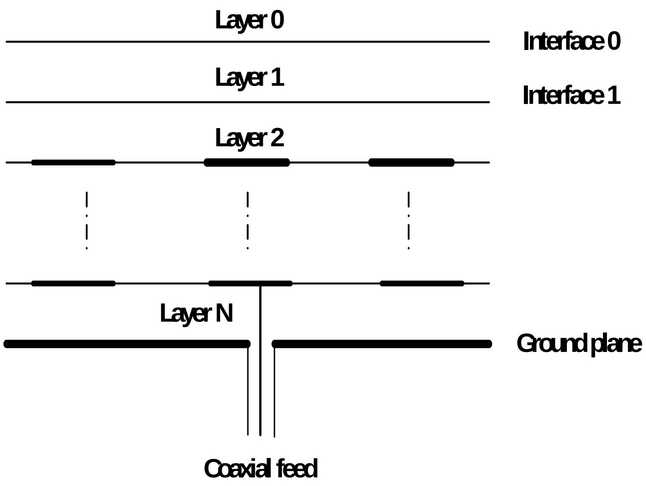
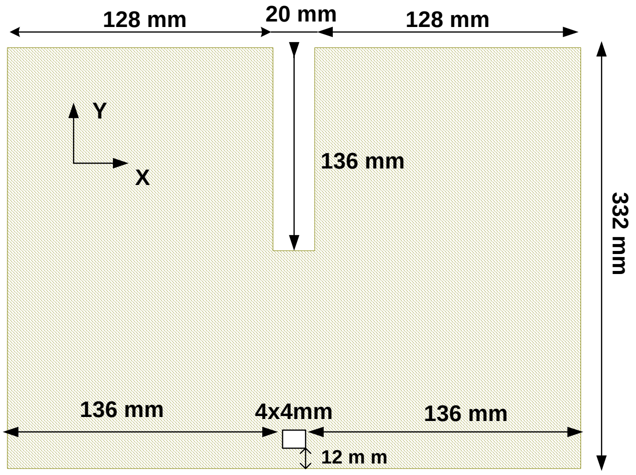


Fig. 2 Geometry of probe feed rectangular microstrip antenna in planar layered medium

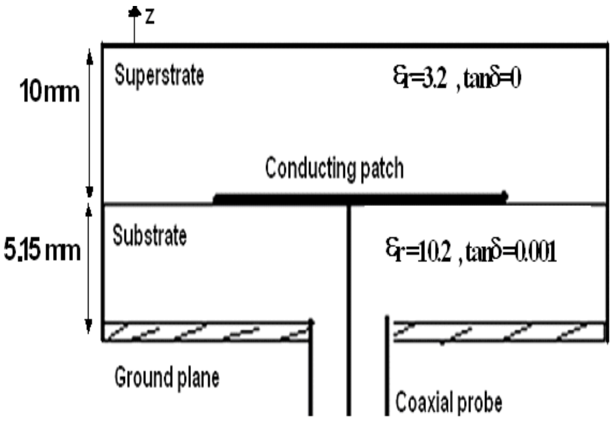
2 Geometry of proposed antenna and calculated results:

2.1 Dielectric cover

Design aspects with geometry dimensions (Fig. 3.) and the obtained simulated results for the proposed antenna are presented below (Fig. 4., 5, 6.).
In Fig. 3. we have present geometrical dimension expressed in mm based on top view and side view. In fig 4. we present return loss , while in Fig. 5. is shown E-field radiation pattern for Phi=0^0. Fig.6 and Fig.7 present area coverage of three, respectively four sectored base station antennas based on our antenna element.



a.) top view



b.) side view

Fig.3. Geometry of proposed antenna (with a Superstrate layer) a.) top view, b.) side view

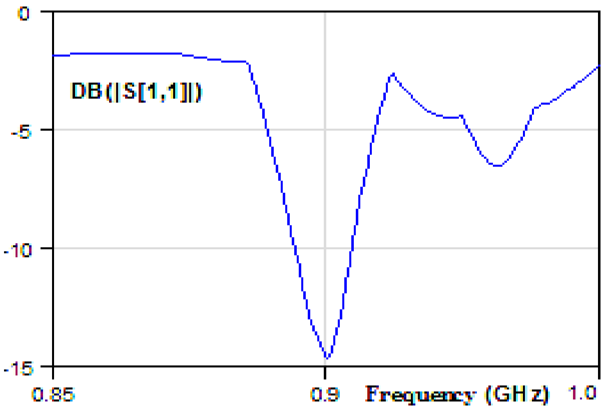


Fig. 4. Return loss of antenna element

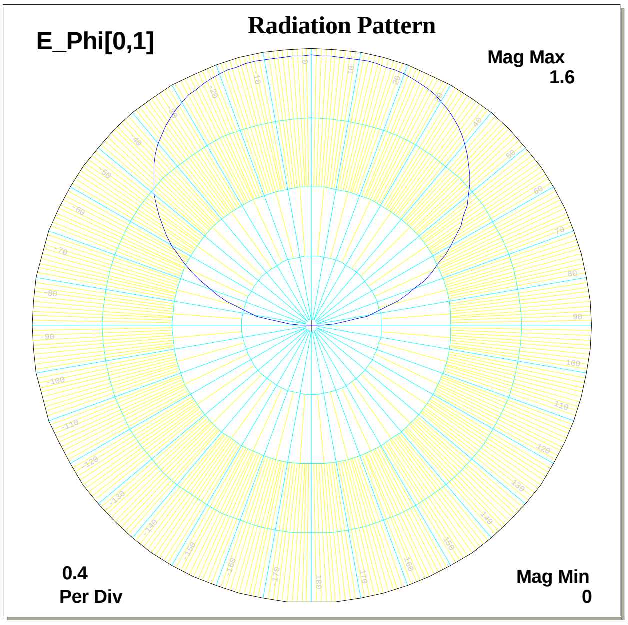


Fig. 5. Radiation pattern (f=0.9Ghz) of antenna element

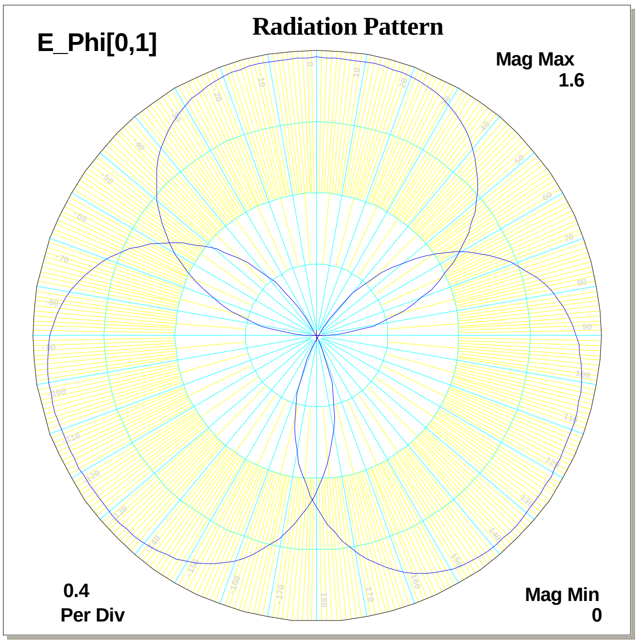


Fig. 6. Area coverage of three sectored base station antennas

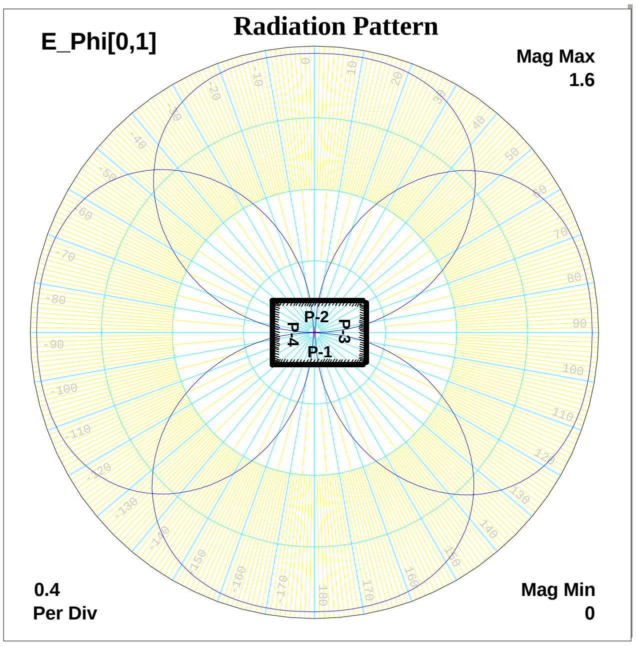
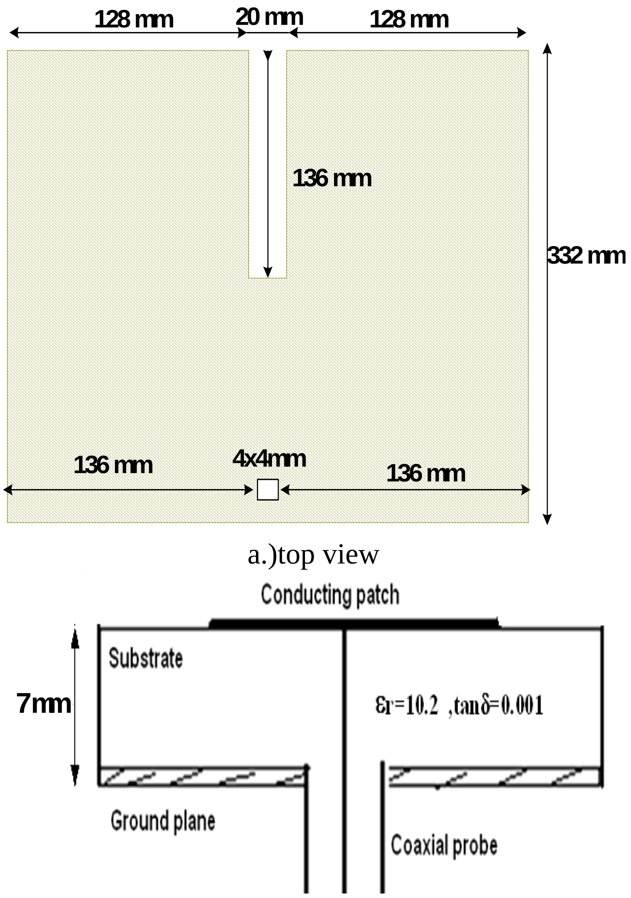


Fig. 7. Area coverage of four sectored base station antennas

2.2 Without dielectric cover -air

Design aspects with geometry dimensions (Fig. 8.) and the obtained simulated results for the proposed antenna are presented below (Fig 9,10) :



a.)top view

b.) side view

Fig.8 Geometry of proposed antenna (without dielectric cover) a.) top view, b.) side view

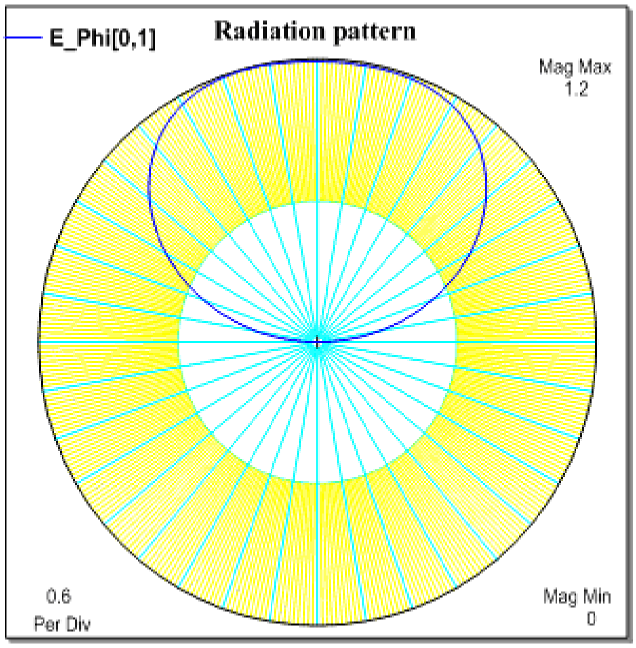


Fig. 9. Radiation pattern (f=0.9Ghz) of antenna element

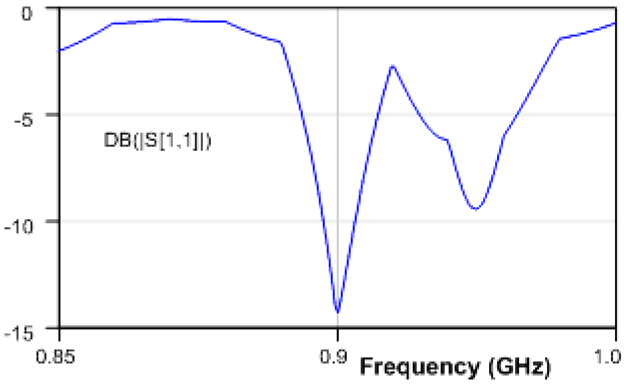


Fig. 10. Return loss of antenna element

3 Conclusion

Microstrip antenna element with U-shaped rectangular patch for sectored coverage of base station antennas of 900 MHz system is good improvement of antenna performance in terms of gain and bandwidth. A superstrate or dielectric cover is used to protect the patch against environmental hazard, while air dielectric is used for a much lighter and cheaper solution.

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