# Design of an Aperture-Coupled Microstrip Antenna for Mobile Communication


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***Abstract* — Microstrip antennas (MSAs) get more and more important in these days. This is mostly due to their versatility in terms of possible geometries, lightweight construction, suitability for integration with microwave circuits, low-cost manufacturing that makes them applicable in many different situations. The aim of this design is to implement an aperture-coupled MSA array that fulfills the requirements of a Base Transceiver Station (BTS) antenna in a mobile communication system. The array consists of nine elements but at first step, the design swells with a single element in this paper. The antenna is designed to operate in the ISM-band (Industrial Scientific Medical) at 2.45GHz, where the bandwidth is 83.5MHz. For widening its bandwidth (BW) a low-permittivity patch substrate with a large thickness is ascribed to this design.**



***Index Terms* — MicroStrip Antenna (MSA), bandwidth (BW), VSWR, Smith chart, dirctivity, gain.**


## I. Introduction

The main property of a mobile communication system is its operating frequency band. Here ISM-band at 2.45GHz is used as the operating (center) frequency band. The exact location of the frequency band is 2400MHz to 2483.5MHz. This leads to BW of 83.5MHz. Thus the relative BW (RBW) is 3.4%. In this work the BW is defined as the frequency range where the antenna inputs are matched to 50Ω. By definition a microwave component is matched when the Voltage Standing Wave Ratio, VSWR≤2. This is a linear polarized antenna but as an option for future enhancement of the system dual polarization can also be implemented.

## II. General Discussion for MSA Design

### *A. Microstrip Radiators*

The heart of an MSA is its upper conductor – the patch of finite dimensions. The amplitude of the surface currents becomes significant when the signal frequency is close to resonance. By taking only the fundamental mode into account the resonant frequency, $f_0$ is calculated which depends on length of the patch, $L_p$, fringing field lengths extension at two open ends, $\Delta L_p$ and effective relative permittivity, $\varepsilon_{eff}$ of the patch substrate.

$$f_0 = \frac{c_o}{2\left(L_p + 2\Delta L_p\right)\sqrt{\varepsilon_{eff}}} \quad (1)$$

The radiation fields at the end of the patch split into tangential and normal components with respect to the ground plane. The normal field components are out of phase because the length of the patch is approximately λ/2. Therefore their contribution to the far field in broadside direction cancels each other. The tangential field components, which are in-phase, combine to give the maximum radiated field normal to the surface of the patch. Therefore this structure can be modeled by two parallel slots, placed half a wavelength apart at the edges of the patch.

### *B. Surface Waves*

The purpose of an antenna is to radiate space waves. But there are also other types of waves excited in an antenna that are unwanted. Among those the surface waves are most nefarious. These waves propagate slightly downwards from the patch into the patch substrate. Then the waves hit the ground plane and are reflected and hit the dielectric-to-air boundary and are again reflected and so on and on. Now these waves abate the signal energy and thus decrease the antenna efficiency. Nonetheless, surface waves introduce unwanted spurious coupling between antenna elements. So, their undesired intruding excitation should be suppressed. For that electrically thick and high-permittivity substrate should be used.

### *C. Excitation Technique: Aperture Coupling*

In aperture coupled antenna the microstrip patch is residing on a separate dielectric slab above the ground plane. Here the feed line is located on a second dielectric slab below the ground plane. These two structures are electromagnetically coupled through an electrically narrow slot, the aperture, into the ground plane between them. So the radiator is shielded from the feed substrate by the ground plane and there is an option of selecting different substrates with different heights for patch and feed.

### *D. Bandwidth and Efficiency*

A general law for MSA is that the absolute bandwidth increases with increasing patch substrate height with decreasing its permittivity. BW increases approximately linear with the substrate permittivity of 1.1. For a substrate thickness of $0.07\lambda_{eff}$ a relative BW increases approximately 9%. In contrast to BW, the efficiency of an MSA decreases with increasing substrate height. So, through a horse-trading, a relatively high efficiency of 95% is predicted for a substrate with $\varepsilon_{rp}$ =1.1 and $h_{rp}$ =$0.07\lambda_{eff}$.

## III. Antenna Design and Configuration

Ideally, as a patch substrate the dielectric substrate should be air with $\varepsilon_r$ =1. Since the structure would need another support to hold the patch, so the most convenient materials are hard foams. Here the foam named Rohacell HF51 with relative permittivity 1.09 is used. In addition, surface waves are due to low permittivity not significantly excited on foam materials. The purpose of the feed line is to carry energy from a connector to the actual antenna tus guided waves can be blasted off. An electrically thin substarte with large permittivity is very suitable for this purpose. Here Neltec NH9338 with relative permittivity 3.38 is used.

Table II shows the geometrical configuration of the designed MSA in a nutshell.

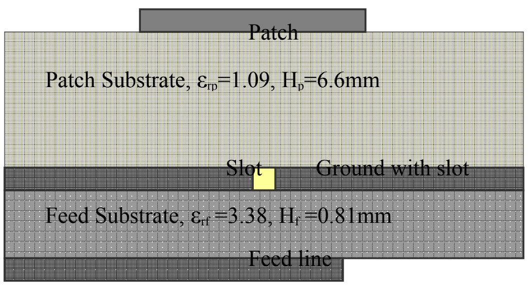


Fig.1. Geometrical configuration of the MSA (side view)

## IV. Results and Discussion

All design and simulation is done by HFSS simulator of Ansoft Corporation.

The reflection co-efficient, $S_{11}$ is 1/3 if we consider VSWR=2. Thus the return loss is -9.54db. At this point, fig. 2. shows us the center frequency is 2.45GHz and the BW is 90 MHz. For this our RBW becomes 3.67%. The design target BW and RBW is 83.5 MHz and 3.4% respectfully. So, we can emphatically achieve the target.

Fig.2. Simulation results for the return loss of the MSA for a frequency sweep from 2.25GHz to 2.75GHz. The center frequency is 2.45 GHz and the BW is 90 MHz.

The Smith chart on fig.3 shows the frequencies from 2.25GHz to 2.75GHz contour for the designed MSA. Among these at our center frequency 2.45 the point C is most closely to the center of the Smith chart which proves that the design termination is almost perfect. Table II shows some numerical representations of the Smith chart for some frequencies

TABLE I

Geometrical Configuration of the MSA

| **Antenna Part** | **Parameter** | **Value** |
|---|---|---|
| **Patch** | Length, Lp | 46.63 mm |
| | Width, Wp | 25.65 mm |
| **Patch Substrate** (Rohacell HF51) | Relative permittivity, $\varepsilon_{rp}$ | 1.09 |
| | Dielectric loss tangent | 0.05142 |
| | Height, Hp | 6.6 mm |
| **Slot** | Length, Ls | 22.23 mm |
| | Width, Ws | 1.71 mm |
| **Feed line** | Length, Lf | 81.21 mm |
| | Width, Wf | 1.88 mm |
| | Stub length, Lstub | 8.32 mm |
| **Feed Substrate** (Neltec NH9338) | Relative permittivity, $\varepsilon_{rf}$ | 3.38 |
| | Dielectric loss tangent | .003 |
| | Height, Hf | 0.81 mm |

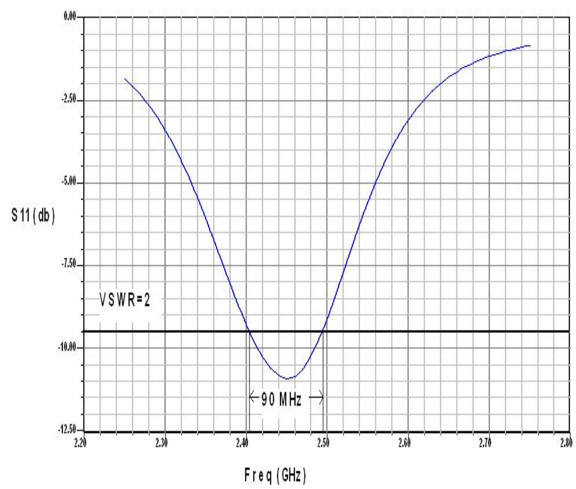


Fig. 2. The frequency sweep from 2.25 GHz to 2.75 GHz while the center frequency is 2.45 GHz and the bandwidth achieved 90 MHz line indicating VSWR=2.

whilst the exact VSWR =1.8 for 2.45GHz is indicated bluntly.

The radiation patterns are shown in fig. 4 to 7 both in

TABLE II

SMITH CHART RESULT FOR VARIOUS FREQUENCIES OF THE MSA

| **Frequency (GHz)** | **2.35** | **2.40** | **2.45** | **2.5** | **2.55** |
|---|---|---|---|---|---|
| **Reflection co-eff (Polar form)** | $0.5 \angle 73^0$ | $0.34 \angle 28.21^0$ | $0.28 \angle -2.25^0$ | $0.35 \angle -28.5^0$ | $0.5 \angle -39.3^0$ |
| **Impedance plane** | 0.787+j0.995 | 1.72+j0.633 | 1.798-j0.044 | 1.9-j0.531 | 1.565-j1.42 |
| **Admittance plane** | 0.489-j0.618 | 0.512-j0.188 | 0.556+j0.014 | 0.491+j0.138 | 0.35+j0.318 |
| **VSWR** | 2.979 | 2.046 | 1.8 | 2.089 | 3.178 |

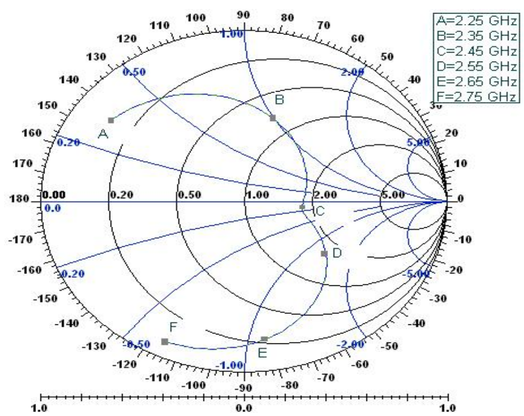


Fig. 3. Smith chart of MSA at pointed (A,B,C,D,E,F) frequencies.

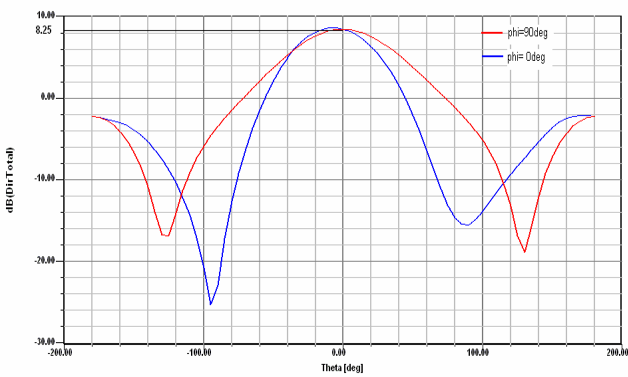


Fig. 4 Total directivity of the MSA at 2.45GHz (Highest radiation intensity at $\varphi=90^0$ is indicated)

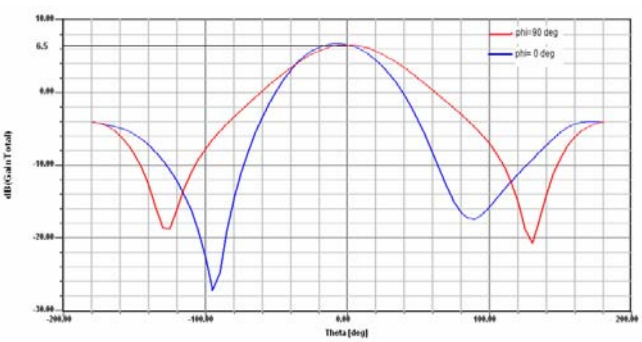


Fig. 5 Total gain of the MSA at 2.45GHz (Highest radiation intensity at $\varphi=90^0$ is indicated)

rectangular and polar form. In fact, the directivity over the isotropic radiator is predicted to be 8.7dBi. But from the calculation of gain and directivity we find the efficiency of the MSA is 78.78%. for this our maximum gain over the isotropic radiator $G= 8.7\text{dBi}+10\log_{10}0.7878 = 7.665\text{dBi}$.

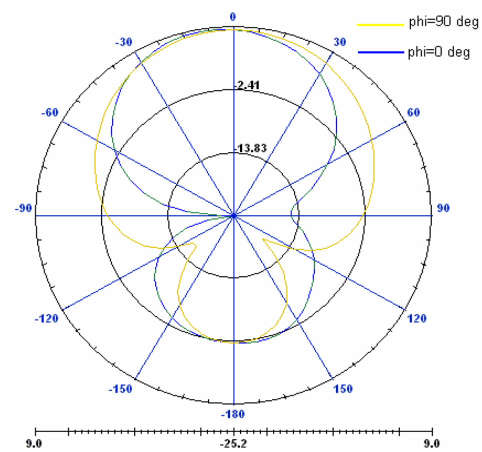


Fig. 6. The directivity pattern of the MSA at 2.45GHz

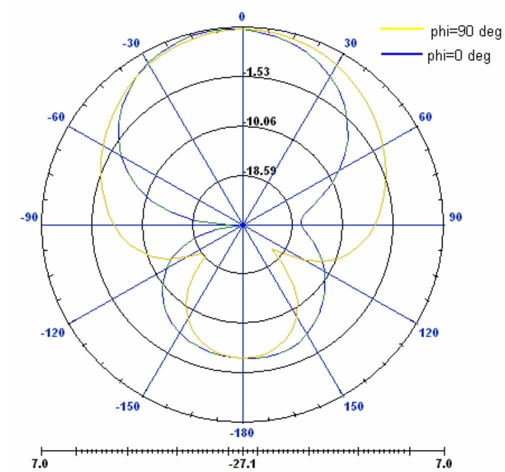


Fig. 7. The gain pattern of the MSA at 2.45GHz

## V. CONCLUSION

This type of antenna mostly used in modern mobile communication. The number of array element probably five or nine or more. But from the design view point it is certainly widen the bandwidth and cost effective. A use of a reflector behind the feed line will certainly enhance the front to back ratio. In future our target is to fulfill that criterion with nine elements.

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