# A MICROSTRIP PATCH ANTENNA WITH COPLANAR WAVEGUIDE FEED LINE


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**Abstract**: This paper deals with the design and simulation of a patch antenna with coplanar wave-guide (CPW) feed line. The coupling from the coplanar line to the patch is accomplished via slot in the ground plane to which the coplanar line is connected with inductive coupling. The return loss can easily be adjusted via the slot length.



**Keywords**: Patch antenna, coplanar waveguide, mm-wave band


## 1. INTDODUCTION

Microstrip patch antennas were found to be suitable for application in millimeter-wave frequency band. As a feed transmission line we propose a coplanar waveguide (CPW), which is approved for feeding a patch antenna [1], [2] and suitable for multilayer fabrication technology. Moreover, this type of transmission line has relatively low attenuation and dispersion [3] and enables us to design easily a wide range of characteristic impedances. We expect that this concept will be a promising solution for planar antennas in millimeter-wave band.

## 2. ANTENNA CONCEPT

In order to combine the advantages of a coplanar line and a microstrip antenna as shown in Figure 1, the patch antenna is placed on one side of the substrate (dielectric constant $\varepsilon_r$ = 2.22, height of substrate is $h$ = 1.58 mm), while a slot is opposite to the patch in the ground plane. The slot is fed with a coplanar line then. The inner conductor of the coplanar line is connected directly across the slot forming an inductive type of feeding.

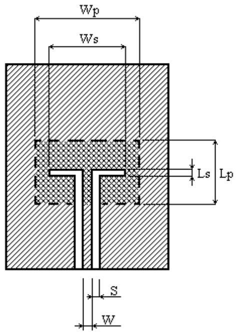


**FIGURE 1:** Basic configuration of patch antenna.

The description of the design procedure patch antenna follows [4]:

We calculate the width ($W_p$) of the patch antenna by [4]:

$$W_p = \sqrt{h\lambda_g}\left[\ln\left(\frac{\lambda_g}{h}\right) - 1\right] \text{ where } \lambda_g = \frac{c}{f_r\sqrt{\varepsilon_r}} \tag{1}$$

and $h$ is height of the substrate, $\varepsilon_r$ is the dielectric constant of the substrate, $\lambda_g$ is the wavelength on the microwave substrate, and $f_r$ denotes the resonant frequency.

We calculate the length ($L_p$) of the patch antenna by [4]:

$$L_p = \frac{c}{2 f_r \sqrt{\varepsilon_{eff}}} \tag{2}$$

Here, $c$ is the velocity of light, and $\varepsilon_{eff}$ is the effective permittivity of the microwave substrate given by 3 [4]

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\frac{1}{\sqrt{1 + 12\frac{h}{W_p}}} \tag{3}$$

The CPW feed structure is show on Figure 2.

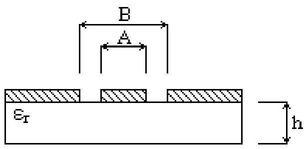


**FIGURE 2:** CPW feed structure.

The description of the design procedure CPW feeder follows [5]:

$$k = \frac{A}{B} \tag{4}$$

$$k' = \sqrt{1 - k^2} \tag{5}$$

$$kl' = \sqrt{1 - kl^2} \tag{6}$$

$$kl = \frac{\tanh\left(\frac{\pi A}{4h}\right)}{\tanh\left(\frac{\pi B}{4h}\right)} \tag{7}$$

$$\varepsilon_{eff} = \frac{1 + \varepsilon_r \frac{K(k')K(kl)}{K(k)K(kl')}}{1 + \frac{K(k')K(kl)}{K(k)K(kl')}} \tag{8}$$

$$Z_0 = \frac{60\pi}{\sqrt{\varepsilon_{eff}}}\frac{1}{\frac{K(k)K(kl)}{K(k')K(kl')}}, \tag{9}$$

where $A$ is the width of track, $S(S = A\text{-}S/2)$ is the width of gap, $h$ is the height of substrate, $\varepsilon_r$ is the dielectric constant of the substrate, $K(k)$ is the complete elliptic integral of the first type, $K(k')$ is the additional complete elliptic integral of the first type. To avoid microstrip line modes, $h >> S$ is recommended. Matlab script is used for the calculation of the characteristic impedance of CPW.

## 3. SIMULATION RESULTS

Numerical values of the antenna dimensions are summarized in Tab. 1.

| | |
|---|---|
| $W_p$ | 22.00 mm |
| $W_s$ | 13.46 mm |
| $L_p$ | 17.37 mm |
| $L_S$ | 1.00 mm |
| $W$ | 3.00 mm |
| $S$ | 0.16 mm |

**Tab. 1:** Dimensions of the patch antenna.

The numerical model of the patch antenna was created in CST Microwaves Studio. The model is shown in Figure 3.

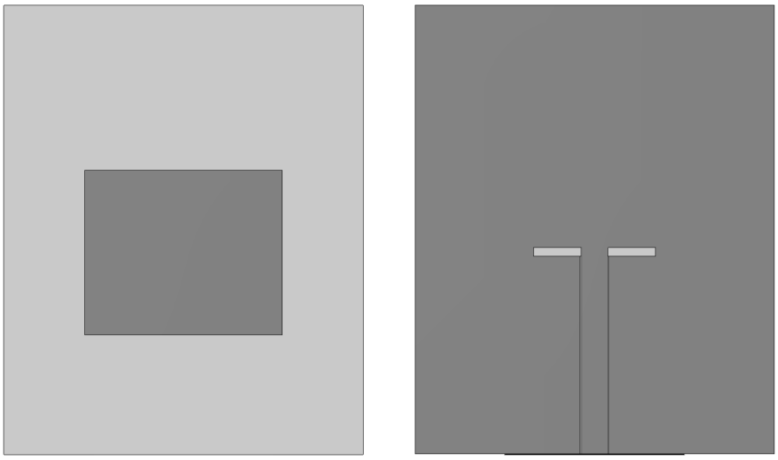

**FIGURE 3:** The model of the antenna – front view (left), back view (right).

In Figure 4, computed frequency responses of the return loss at the antenna input are shown.

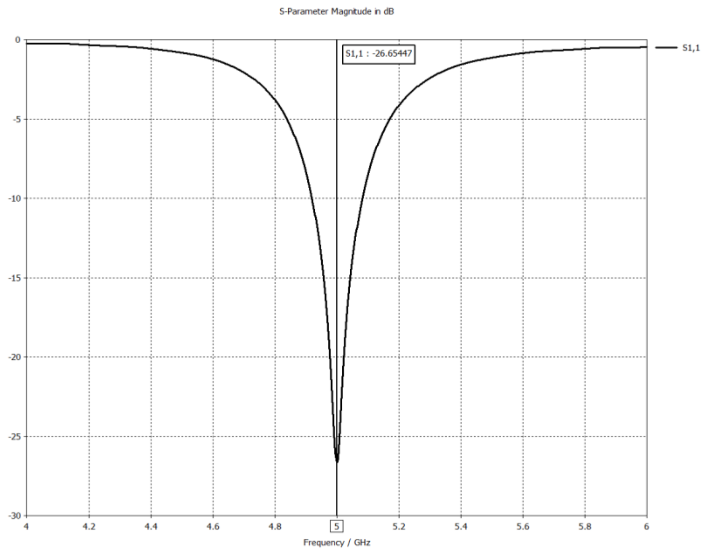


**FIGURE 4:** Frequency response of the return loss of the patch antenna.

Antenna bandwidth (–10 dB return loss) was 3.2% for inductive coupling. Voltage standing wave ratio (VSWR) at resonant frequency is VSWR = 1.05. The real and imaginary components of the input impedance are shown in Figure 5. Input impedance of the patch antenna is $Z_0 = (49.23 + 4.55j)\ \Omega$.

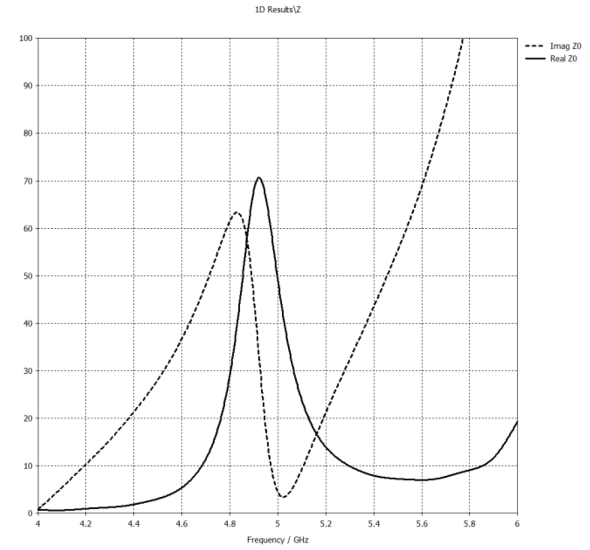


**FIGURE 5:** Input impedance of patch antenna.

Figure 6 shows parametric sweep return loss and resonant frequency depending on slot length. Figure 7 shows radiation pattern of the patch antenna.

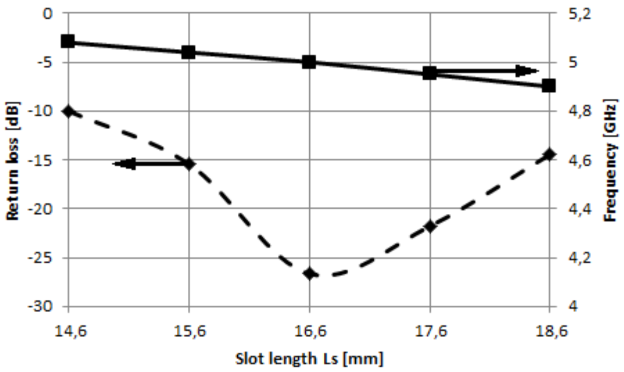


**FIGURE 6**: Return loss and resonant frequency of the antenna.

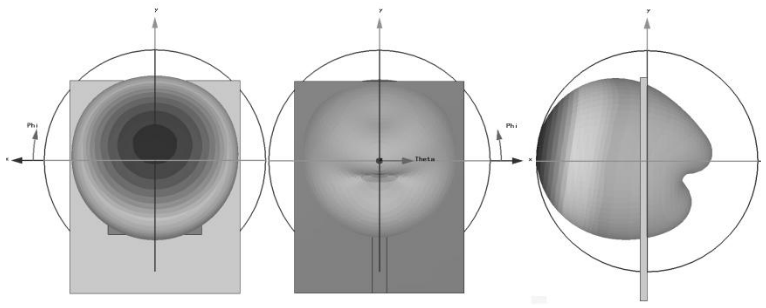

**FIGURE 6**: Radiation pattern of the patch antenna (G = 7.7 dB@5 GHz).

## 4. CONCLUSIONS

The paper describes the design and simulation patch antenna with coplanar feed line. Good impedance matching was accomplished with inductively coupled slot. As known from other slot coupled patches, some radiation is found on the backside of the structure as long as the slot is not in resonance, however, this backward radiation can be kept relative small. We expect that this concept will be promising solution for planar antennas in millimeter-wave band.


## ACKNOWLEDGEMENT

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