

# Models for Doppler' Radar for Beam Streaming Capabilities

Peter Z. Petkov, Rosen Vitanov and Ivaylo Nachev  
Faculty of Telecommunications at Technical University of Sofia  
8 Kl. Ohridski  
Blvd, Sofia 1000, Bulgaria  
[pjpetkov@tu-sofia.bg](mailto:pjpetkov@tu-sofia.bg)  
[rosenvitanov@gmail.com](mailto:rosenvitanov@gmail.com)  
[ivaylonachev@yahoo.com](mailto:ivaylonachev@yahoo.com)



**ABSTRACT:** *In the current work we have designed a Doppler' radar which will accommodate more coverage and beam steering capabilities. The new design antenna permits tiny physical attributes, low cost and ensure more reliability that is possible for autonomous flying vehicle to find obstacles in flights. It will help to modify the positions.*

**Keywords:** Radar, Antenna, Patch Antenna, Patch Array, Phased Array, Transmission Line Phase Shifter, Quadcopter, Autonomous Flying Vehicle

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## 1. Introduction

We are witnessing a technological boom, where more and more automatic devices do complex operations and services in areas, recently possible only for humans. Autonomous flights by unmanned air vehicles (UAV) is one of those. The great challenge is to detect and overcome an obstacle in midflight, without being interrupted. For this purpose – a microwave radar with enhanced range and integrated beam-steering functionality is implemented. In this way UAV may test the upcoming trace for any obstacles and avoid collisions during a flight.

Most antennas have a fixed radiation pattern, which is a inconvenience, when used in drones, because it should stop in one place and test the area by turning around using its propellers. A practical solution to this problem is usage of array antenna with scan.

In this case most appropriate is to use a series patch array. It may sweep the direction of the beam by varying electronically the phase of the radiating element, thereby producing a moving pattern with no moving parts.

## 2. Corporate Feed Network Patch Array Design

An important step when designing patch antenna is to take into account dielectric substance on which patches are made. The employed substrate for the proposed design is Rogers RO 4003 with thickness  $h = 0.508\text{mm}$  and Dissipation factor  $\tan\delta = 0.0027$ . In order to improve the bandwidth and efficiency of antennas, a design method called “suspended substrate” is chosen, where the thickness of the gap between ground plane and antenna is  $\Delta = 1\text{mm}$ . In this method we use the equivalent Dielectric constant (7). Distribution of the elements of the simulated model, as with radars frequency  $f_c = 10.525\text{GHz}$  we have wavelength  $\lambda = 28.50\text{mm}$ , and  $\lambda_g = 22.6150\text{mm}$ . For calculation of antenna dimensions a straightforward basic algorithm is proposed:

**Step 1:** Calculation of width (W): Width of the Micro strip antenna is given by the equation:

$$W = \frac{c}{2f_c} \left( \frac{\epsilon_r + 1}{2} \right)^{-\frac{1}{2}} = 12.2208\text{mm}, \frac{W}{h} > 1 \quad (1)$$

Where  $c$  is the speed of the light  $c = 3 \times 10^8$ ,  $\epsilon_r$  is a dielectric constant of substrate,  $f_c$  is radar frequency and  $h$  is substrate thickness.

**Step 2:** Calculation of Effective Length (L): Length of the microstrip radiator is given by:

$$L = \frac{c}{2f_c \sqrt{\epsilon_r}} = 11.3\text{mm} \quad (2)$$

Where  $f_c$  is radar frequency and  $\epsilon_{eff}$  is effectively dielectric constant of substrate

**Step 3.** Calculation of the Length extension ( $L_{ext}$ ): The actual length is obtained by the equation (accounting for the fringing fields):

$$L_{ext} = 0.412h \frac{(\epsilon_{eff} + 0.3) \left( \frac{W}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left( \frac{W}{h} + 8 \right)} = 0.8825\text{mm} \quad (3)$$

**Step 4:** Calculation of the actual length of the Patch ( $L_{eff}$ ): The actual length of the patch is given by:

$$L_{eff} = L + 2L_{exp} = 12.9650\text{mm} \quad (4)$$

Determination of effective dielectric permittivity  $L_{eff}$ :

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left( 1 + 10 \frac{h}{W} \right)^{0.5} = 1.5886 \quad (5)$$

The length of the guided wave:

$$\lambda_g = \frac{\lambda}{\sqrt{\epsilon_{eff}}} = \frac{c}{f_c \sqrt{\epsilon_{eff}}} = 22.6150\text{mm} \quad (6)$$

Influence of the gap is taken into account:

$$\epsilon_{req} = \frac{\epsilon_r * (h + \Delta)}{\epsilon_r + h * \Delta} = 1.72 \quad (7)$$

Where  $\epsilon_r$  is a dielectric constant of substrate and  $\Delta$  is thickness of the gap. The new dielectric constant in technology with suspended substrate is marked with  $\epsilon_r eq$ , where the characteristics of the air are also taken into account.

Connection between radiating antenna and phase delay line control system is achieved using SMA connectors with impedance  $Z_0=50\Omega$  which is low enough to not interfere with antenna's parameters.

In table 1 are presented the values obtained for dimensions of the antenna components. Fig.1 shows simulation model of corporate feed network patch array. [1] [2][3].

	W [mm]	$L_{eff}$ [mm]
Calculated	12.2	12.96
After simulation	13.8	11

Table 1. Alues Obtained for Dimensions of the Antenna Components

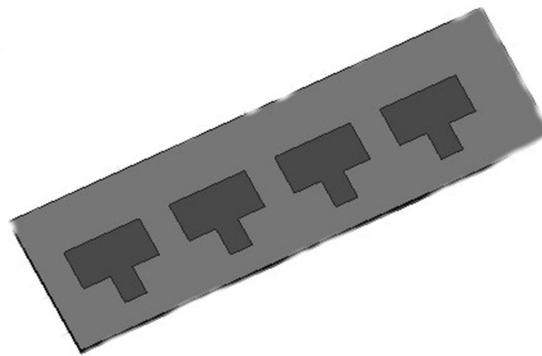


Figure 1. Corporate feed patch array – simulation model

### 3. Transmission Line Phase Shifter

Described phased antenna array uses a hybrid T junction system that divides the input power in 4 equal parts. In this paper is described how - by changing electric length of microstrip lines (ML), changes the phases of fed signals, thus steering the beam (figure 2). It is required to change the position of the beam in 3 different degrees: -15; 0; +15 deg. page.

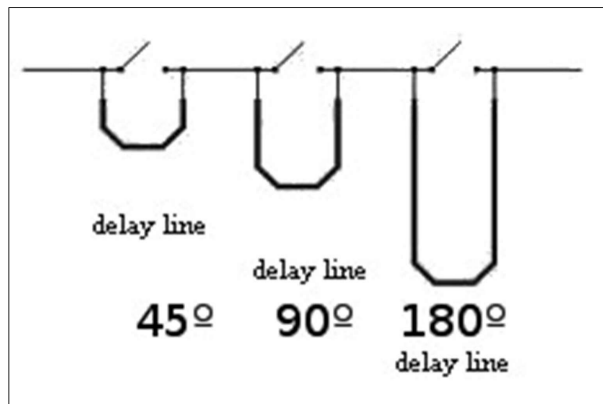


Figure 2. Switched line phase shifter

In the switched-line phase shifter, phase shifting is obtained by varying the length of the antenna feed line. The phase delay in the feed line is calculated from:

$$L_{\text{effective length}} = \frac{\beta c}{2\pi f \sqrt{\epsilon_{\text{eff}}}} \approx 2.877 \text{ mm} \quad (8)$$

$L_{\text{effective length}}$  - Change in length;

$\beta$  - Propagation constant;

$c$  - Speed of light;

$\epsilon_{\text{eff}}$  - Effective dielectric constant;

$f$  - Operating frequency;

Formula (8), leads to conclusion that phase differences between each patch should be 2.877mm, and using electromagnetic simulator equals 45 deg. That's confirm from simulations in the design process Simulation showed best results with each phase line doubled the length on the previous. This is shown in table 2. [4][5]

Beam steering	Patch1	Patch2	Patch3	Patch4
0°	0°	0°	0°	0°
+15°	0°	45°	90°	180°
-15°	180°	90°	45°	0°

Table 2. Relation Between Beam Steering and Patch Phases

#### 4. Phase Delay Line Control System

On figure 3 a graphical relation between radiating antenna, feed, phase delay lines and hybrid T junctions is shown. Building

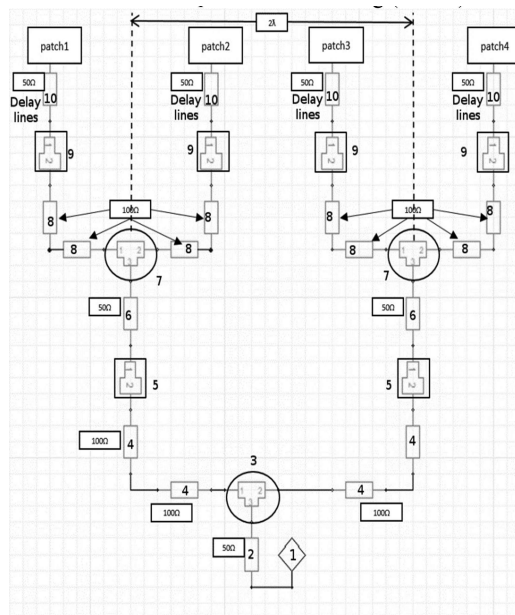


Figure 3. Block diagram of radiating antenna

such a system requires input power to be divided in 4 equal parts, described below. Initially, the signal “P” enters at the input point (1). Then, using a 50 Ohm microwave line (2) is passed to the first T junction (3), designed to divide the energy into two equal parts “P / 2”. This is accomplished by two 100 Ohm MLs(4). Then the impedance is again converted to 50 Ohm (6) by step – work like impedance transformer (5). The energy separation is repeated again by a second group of fT junctions (7) to 100 Ohm microwave lines (8), the final result is “P / 4”. Using ML (9), the impedance is again lowered to 50 Ohms and “P / 4” passes through delay line (10) to the radiating element. Beam steering is accomplished by switching between microstrip lines with different lengths , using PIN diodes. This leads to required beam scanning (tabl. 2).

### 5. Simulations Result

Shown are results from simulations. In fig. 4 is displayed the return loss of the antenna. Figure 5, shows elevation radiation pattern. Figs. 6a, 6b,6c show represent the beam in azimuth, steered a the three available angles – 0 deg, -15 degs and +15 degs. In table 3, a comparison of gains in beam’s different state.

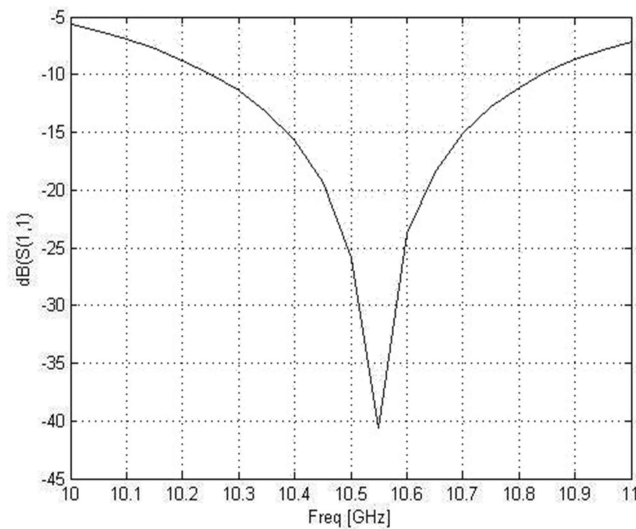


Figure 4. Antenna bandwidth (S11)

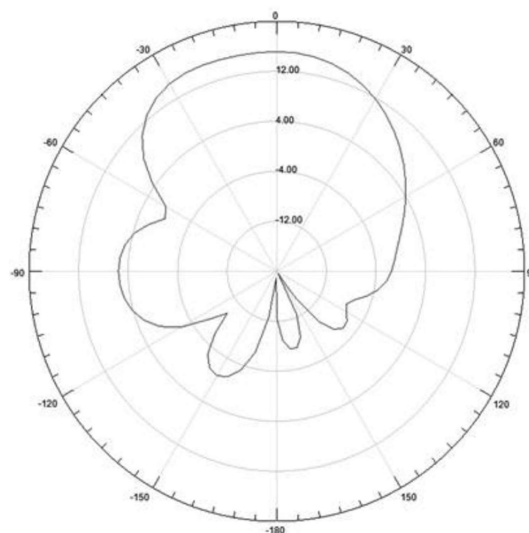


Figure 5. Radiation Pattern elevation

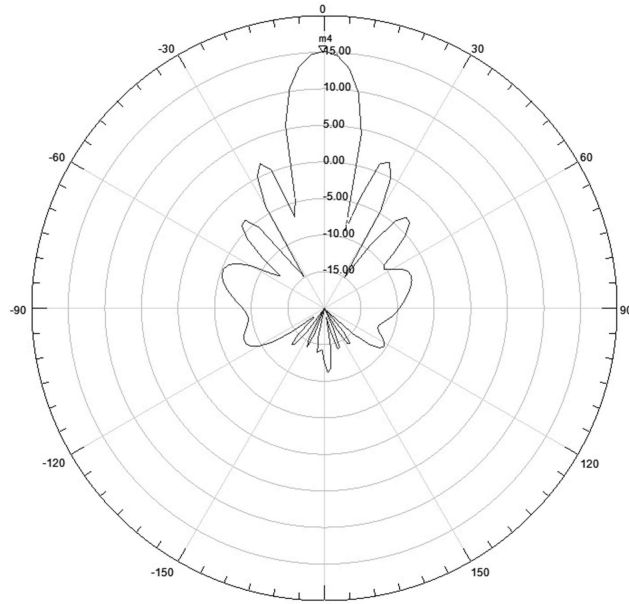


Figure 6a. Radiation Pattern azimuth 0deg

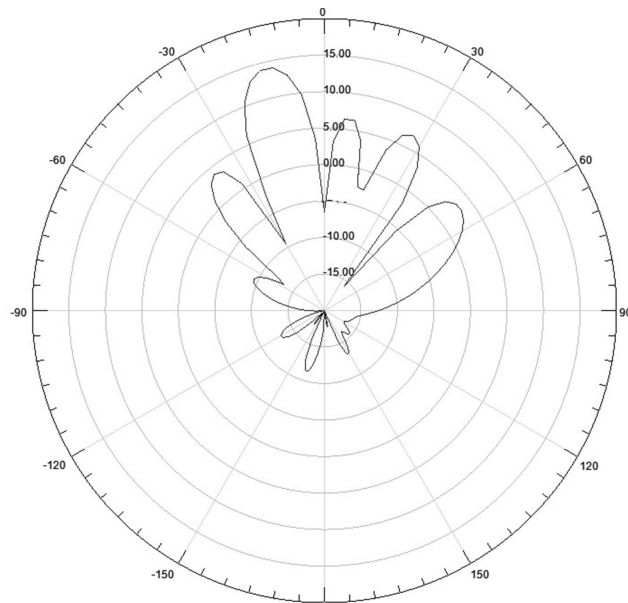


Fig. 6b. Radiation Pattern azimuth -15deg.

	Gain[dB]
Patch array 0deg.	15.1
Patch array -15deg	14.7
Patch array +15deg	14.67

Table 3. Comparison of Gains In Beams Different State

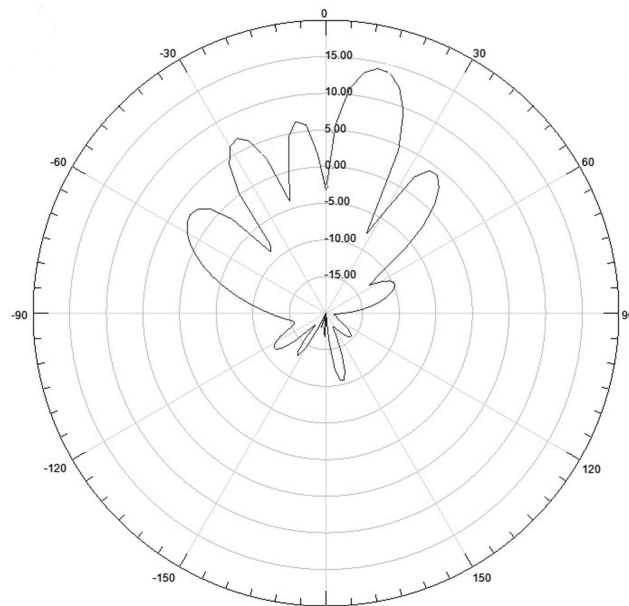


Figure 6c. Radiation Pattern azimuth +15deg

## 6. Conclusion

Using microwave delay line phase shift in systems such as considered allows an electronic scan of the antenna beam. Integrated antennas in the HB100 module can be used for automatic and non-intrusive obstacle detection system for quadcopters and other unmanned vehicles.

## References

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