Investigations on Ultra-Wide Bandwidth Pentagon Shape Microstrip Slot Antenna Backed by Reflecting Sheet for Directional Radiation Patterns

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Abstract

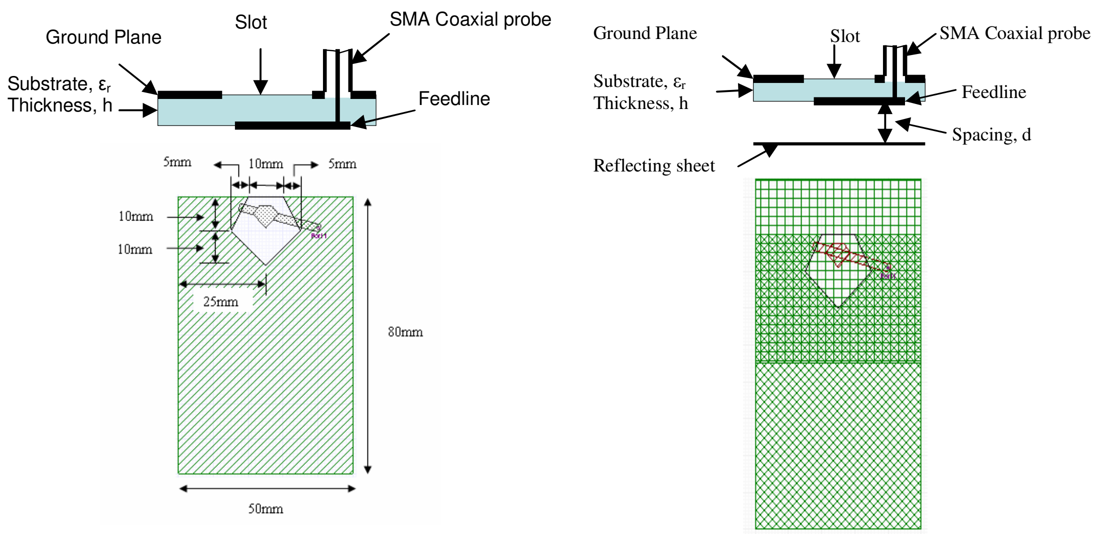
Investigation results of an ultra-wideband (UWB) pentagon shape planar microstrip slot antenna backed by a conducting reflecting sheet is presented, which aims to provide directional radiation patterns. The antenna shows an impedance bandwidth of 129% from 2.50GHz to 11.50GHz with the gain variation from 7dBi to 3dBi for a spacing d= 20 mm. However, better directionality can be obtained using a combination of d = 5mm and 10mm spacing with reduced matching levels. The antenna has been fabricated and will be experimentally tested. This UWB antenna can find applications in compact devices where controlled back radiation is desired.

1. Introduction

The ultra-wideband (UWB) frequency ranges from 3.10GHz to 10.6GHz as per the specifications of Federal Communications Commission (FCC). The availability of such a large bandwidth lends to high data rate transmissions such as in the multimedia communications [1]. The compact UWB planar antennas are generally microstrip slot antennas excited using different feeding techniques and provide omni-directional radiation patterns [2]. However, some wireless communication devices may require controlled backlobe radiation or a directional pattern such as obtained using a microstrip antenna [3]. But a directional antenna with UWB performance is not available, especially in planar and compact form. However, there are several types of traditional UWB antennas including the self-complementary spiral antenna, bi-conical antenna, and Log-periodic antennas, which are designed for UWB communication systems [4]. But, most of these antennas cannot be used for current compact UWB wireless communication systems because of their design complexity, size, weight and cost limitations. The tapered slot Vivaldi elements and their array are typically 2-3 wavelengths long at the end of high band, but it provides 3:1 bandwidth close to the UWB requirement [5-6]. These antennas are three-dimensional so may not be an option for most of the wireless communications devices. A reduction in antenna size was obtained with the “bunny ear” antenna element providing 4:1 bandwidth more than the UWB range, which is half-wavelength long at the higher frequency end and quarter wavelength at the lower frequency end but has poor radiation efficiency [7]. Therefore, the availability of a planar, and compact antenna candidate with the directional radiation patterns within UWB range, as proposed in this paper, will find applications in novel wireless communication applications. The conducting reflecting sheet can be implemented with the antenna as back plate in compact devices. The simulations were carried out using the Ansoft Corporations Designer and high frequency structure simulator (HFSS), both full wave analysis tools. The antenna has been fabricated and will be tested for its impedance and radiation pattern characteristics. The remaining results will be presented during the General Assembly.

2. Geometry of Planar Ultra-Wide Bandwidth Antennas

The geometries of the ultra-wide bandwidth (UWB) planar pentagon shape microstrip slot antennas without and with the reflecting sheet are shown in Figure 1(a-b), respectively. Both consists of a pentagon shape slot on a microstrip substrate (RT Duroid 5880, $\varepsilon_r = 2.2$, h=1.58mm), a tilted microstrip transmission feed line and a pentagon stub for wideband impedance matching. The feed line tilt is 15^o. The antenna is fed through a 50Ω coaxial SMA connector connected to a 50Ω microstrip transmission line. The ground plane size for the antenna is kept 50mm × 80mm which is similar to a computer PCMCIA card (personal computer memory card interface adapter) and is also based on the study presented on microstrip slot antennas in [8]. The pentagon shape slot requires only 25% length on the ground plane leaving enough space for the RF circuitry. A square reflecting sheet of dimension 50mm × 50mm is placed at a variable spacing d from 5mm to 35mm from the antenna, as shown in Figure 1(b), for the investigations of the effect of reflecting sheet on achieving the directional radiation patterns. Note that a conventional microstrip slot antenna provides omni-directional pattern.



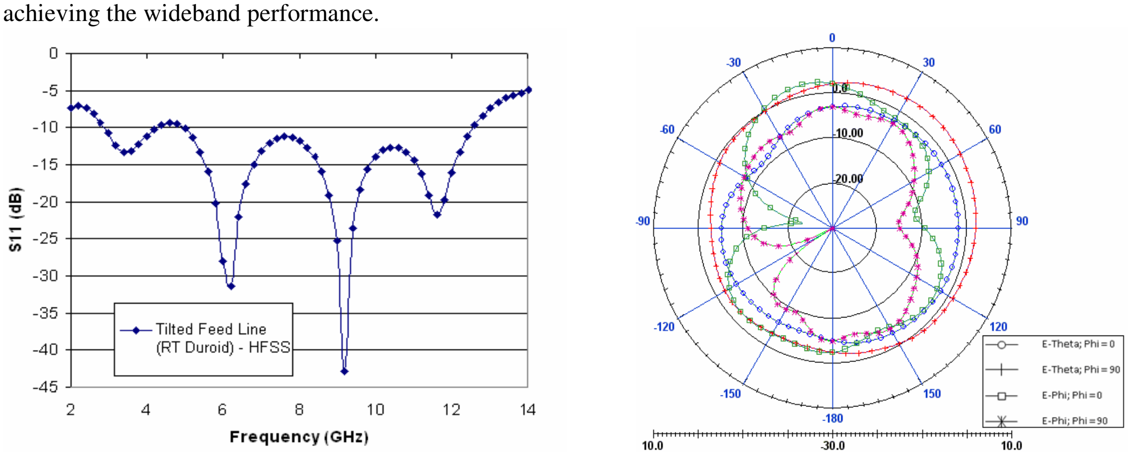
(a) (b)

Figure 1: Geometry of the pentagon shape microstrip slot antenna with the tilted feed line (a) without reflecting sheet, and (b) backed by a reflecting perfect conductor sheet at a spacing d.

3. Simulation Results and Discussions

3.1 Pentagon Shape UWB Microstrip Slot Antenna Without Reflecting Sheet

The return loss versus frequency plot for the antenna without the reflecting sheet (Figure 1(a)) is shown in Figure 2(a). It is observed that a wide impedance bandwidth of about 127% (w.r.t. S_{11} = -10dB) is achieved covering frequencies from 2.8GHz to 12.6GHz. Figure 2(b) shows the radiation patterns at 7GHz. It is observed that a fairly good omni-directional radiation pattern can be obtained. The effect of high cross-polarization components is observed throughout the bandwidth, which may be due to the pentagon shape stub used for achieving the wideband performance.



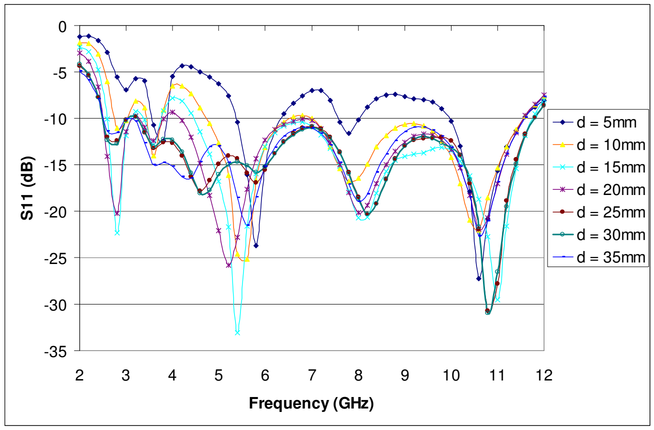
(a) (b)

Figure 2: (a) Return loss (S_{11}, dB) vs. frequency (GHz), and (b) Gain radiation pattern at 7GHz. The antenna was simulated using the Ansoft HFSS which is a finite element method (FEM) program.

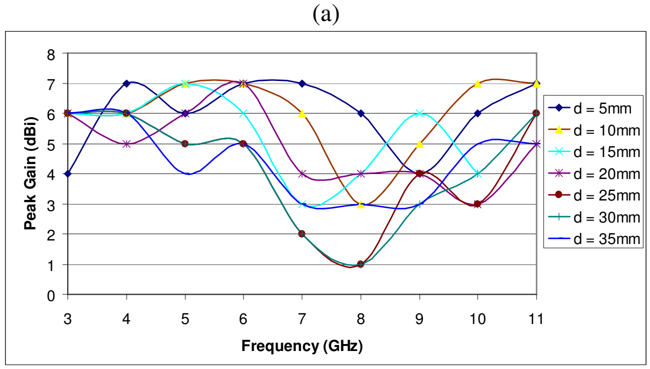
3.2 Pentagon Shape UWB Microstrip Slot Antenna With Conductor Reflecting Sheet

Figure 3 shows the return loss and peak gain performance of the antenna with the conducting reflecting sheet height variation from d = 5mm to 35mm (antenna geometry as shown in Figure 1(b)). Further, from Figure 3(a) it can be observed that, for d=5mm the antenna shows mismatch and multiple resonances. For d = 10mm to d = 35mm variation, the antenna is matched for frequencies from 5GHz to 11.70GHz. For d = 20mm to d = 35mm, the antenna is matched from close to 2.50GHz to 11.5GHz. The bandwidth is about 129% (w.r.t. S_{11} = -10dB) covering 2.5GHz to 11.5GHz with d = 20 mm, which exceeds the specified UWB range.

Similarly, the gain variation is shown in Figure 3(b) and it can be observed that, as the reflecting sheet spacing varies the peak gain changes. However, from d = 5mm to 20mm, the gain variation is almost in the same range between 7dBi and 3dBi. With further increase in the spacing from d = 25mm to d = 30mm, the minimum gain level decreases to even 1dBi although maximum gain is still 6dBi. For both d = 20mm and d = 35mm, the gain variation is again between 7dBi and 3dBi. This gain variation happens because a selected spacing d is electrically different for different frequencies within the bandwidth. This, in turn, may be causing cancellation of inphase currents, and consequently, a drop in gain.



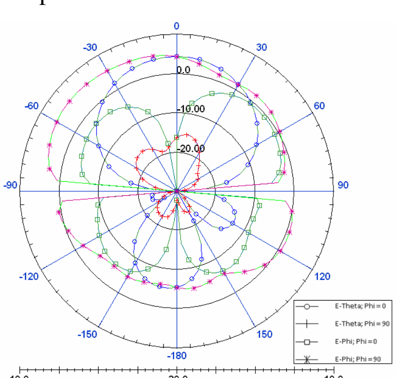
(a)



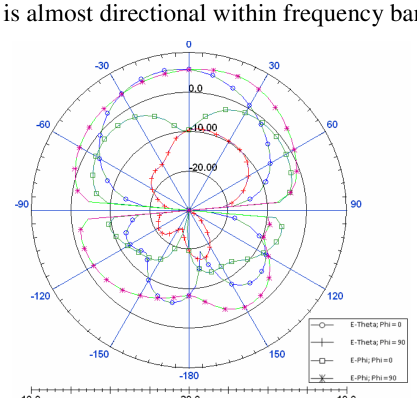
(b)

Figure 3: Effect of reflecting sheet on the pentagon shape microstrip slot antenna with the variation of spacing d from 5mm to 35mm, (a) Return Loss (S_{11}, dB), and (b) Peak gain (dBi).

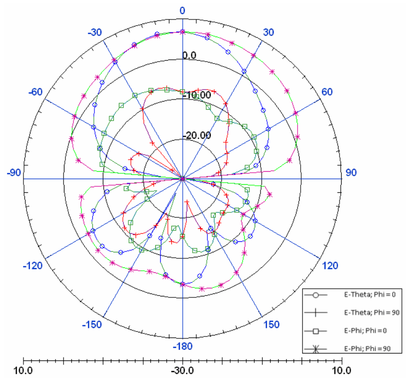
However, a spacing of d=20 mm can be found to be a spacing where gain changes between 7dBi to 3dBi, whereas the impedance matching is 129% (from 2.5GHz to 11.5GHz) more than the UWB requirement. The radiation patterns for this case showed that as frequency increases, the patterns show ripples and cross-polarization is almost equal to the co-polarization patterns. Also the directionality is not good at all frequencies. Therefore, it may be preferred to select a variable spacing (for example a combination of d = 5mm and 10mm) such that the directional patterns with gain variation between 5dBi to 7dBi is obtained, if reduced impedance matching level ($S_{11} \leq -5$dB) can be acceptable for some wireless communication applications. Figure 4 shows radiation patterns for the latter case. It can be observed that pattern is almost directional within frequency band.



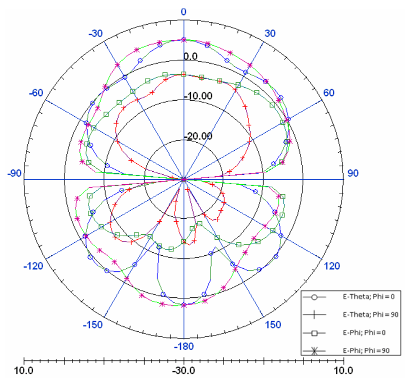
(a) d=10mm, 4GHz



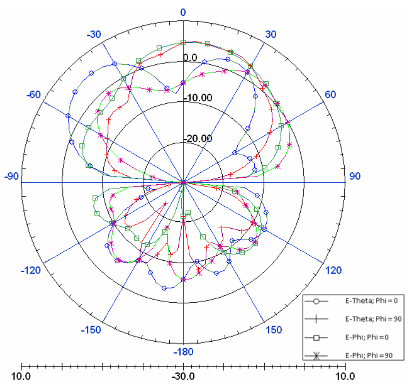
(b) d=10mm, 5GHz



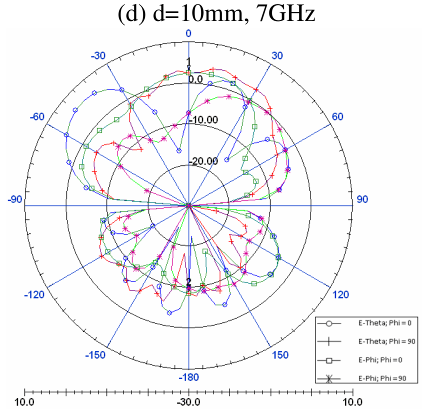
(c) d=5mm, 6GHz



(d) d=10mm, 7GHz



(e) d=5mm, 10GHz



(f) d=5mm, 11GHz

Figure 4: Gain radiation patterns for the reflecting sheet backed antenna with selected spacing of d = 5mm or 10mm for following frequencies (a) 4 GHz, (b) 5 GHz, (c) 6 GHz, (d) 7 GHz, (e) 10 GHz, and (f) 11 GHz. The nulls along the horizon ($\theta = 90^o$) is a limitation of the Ansoft Designer, which is a method of moment (MOM) program. Compare this with the HFSS simulated result presented in Figure 2(b) where no such null is visible.

4. Conclusion

Investigation results of an ultra-wideband (UWB) pentagon shape planar microstrip slot antenna backed by a conducting reflecting sheet is presented, which aims to provide directional radiation patterns. The antenna shows an impedance bandwidth of 129% from 2.50GHz to 11.50GHz with gain variation from 7dBi to 3dBi for a spacing of d= 20 mm. However, better directionality can be obtained using a combination of d = 5mm and 10mm spacing with reduced matching levels. The antenna has been fabricated and will be experimentally tested. Remaining results will be presented during the General Assembly. The antenna can find applications in compact devices requiring UWB frequency range, and where controlled back radiation is generally desired.

References

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