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High Gain and High Directivity UWB Bow-tie Antenna with High Impedance Metamaterial Surface

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1. Introduction

Ultra wideband (UWB) is a carrierless short range communication technology and it can offer high data rates at short distances with low power. [1]- [3] The antennas are preferred to be low profile. Moreover, to avoid electromagnetic interference with the other electronic devices of the system, it is preferable to minimize the backward radiation. To fulfill the requirements on radiation patterns, metal surfaces are used like antennas reflectors. Nevertheless, metal reflects incident waves with a phase shift of 180°. Therefore, when the antenna is too close to the reflector plane, there is a destructive interference between incident and reflected waves. A solution can be to place the antenna at a distance of $\lambda/4$ from the reflector. The $\lambda/4$ was 25 mm at 3 GHz in free space. Thus this solution is not interesting for low profile structures. Introducing high impedance surface (HIS) like reflectors, the antenna can be placed closer to the reflector while preserving antenna profile in order that HIS reflects incident waves in phase.[4] Unfortunately, general HIS are not ultra wideband. The aim of this work is to design a low profile, high gain and ultra wideband antenna. In this paper, bow-tie antenna on HIS was fabricated and the effect of HIS on a bow-tie antenna was investigated.

2. Experimental

The bow-tie antenna has been chosen as shown in Fig.1. Figure 2 shows the structure of a fabricated bow-tie antenna on HIS. HIS was consisted of 2-D linear array of square patches. The bow-tie antenna is fabricated on a FR4-substrate ($\varepsilon_r = 3.8$) with HIS. Antenna length (L) and flare angle (θ) of the fabricated bow-tie antenna were 54 mm and 90°, respectively. The HIS structure was made up with 15x15 square patches. The patch's width (X) and gap between patches (g) of the fabricated HIS were 7.3 mm and 1 mm, respectively. The substrate with bow-tie antenna and HIS was placed on two FR4-substrates. The complete structure has a total size of 124.5x124.5 mm^2 with a thickness of 4.8 mm ($\lambda/20$ at 3 GHz where λ is the wavelength in free space). Figure 3 shows a measurement set-up. Scattering parameter measurement set-up in frequency domain was composed of a vector network analyzer HP8510C, 180° hybrid couplers (1-12.6 GHz), signal-signal (SS) probes, double ridge horn antenna and a microwave probe station.

3. Result and discussion

Figure 4 shows the phase of the reflection coefficient (S_{11}) in the case that a plane wave illuminated the patches of HIS perpendicularly in simulation. The incident wave and reflection were in phase at the frequency which the phase of S_{11} is equal to 0. The HIS operating frequency was reduced as X or HIS-substrate thickness (t) increased. Figure 5 shows the HIS operating frequency as a function of patch's width when t is 1.6, 3.2 and 4.8 mm. The HIS operating frequency was changed in 3-4 GHz when t was 3.2 mm. Figure 6 shows the directivity pattern without GND, with GND and with GND and HIS at 3.4 GHz in simulation. In the case of the antenna with GND, the vertical radiation was canceled by a destructive interference between incident and reflected waves. The influence was improved by use of HIS and the vertical gain was improved 8.4 dB, comparing with the antenna without GND and HIS. Figure 7 shows the frequency dependence of the vertical radiation. The gain decreased at 4 GHz with HIS. Figure 8 shows the vertical gain when t is 1.6, 3.2 and 4.8 mm. When t is 3.2 mm, the change of the gain was the smallest of the three. Figure 9 shows the gain dependence on X while X + g = 8.3 mm in HIS with 15x15 array. The gain at 4 GHz decreased as X was increased. Figure 10 shows the gain dependence on the number of HIS patches. The frequency when the gain was reduced became higher as the number of HIS patches was reduced. The 3dB band was improved to 3.3-4.2 GHz when HIS patches were 11x11 patches. Figure 11 shows S_{11} versus frequency for the antenna with HIS of 11x11 patches and without HIS. The bandwidth was improved from 0.3 GHz to greaten than 3 GHz by use of HIS. Figure 12 shows transmission coefficient (S_{21}) versus frequency for the antenna with and without HIS. S_{21} was improved approximately +17.4 dB at 3.4 GHz by use of HIS.

4. Conclusion

We demonstrated the effect of HIS on the directivity and gain of UWB bow-tie antenna. The transmission gain was improved by +17.4 dB and the bandwidth was improved from 0.3 to 3.0 GHz. Consequently, HIS can be applied to UWB antennas for gain improvement.

Acknowledgement

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References

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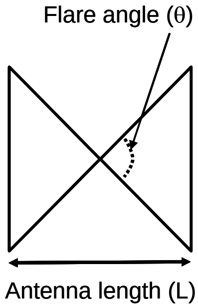

Fig. 1. Bow-tie antenna structure.

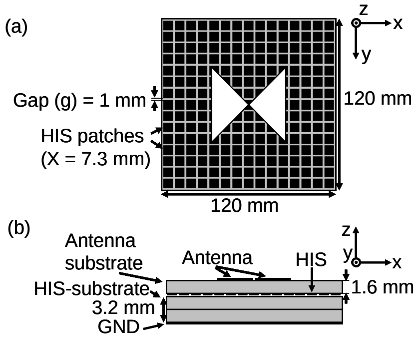

Fig. 2. Structure of fabricated high impedance surface. (a) Top view. (b) Cross-section view.

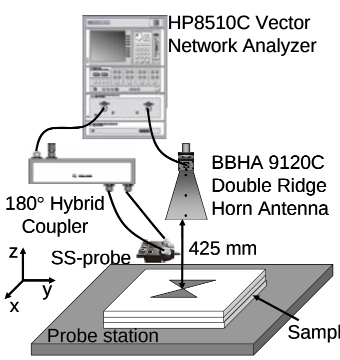

Fig. 3. Experimental set-up.

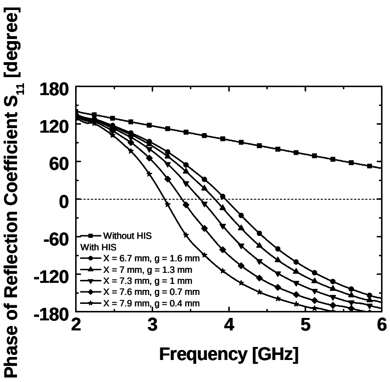

Fig. 4.The phase of S-parameter for reflected wave from HIS.

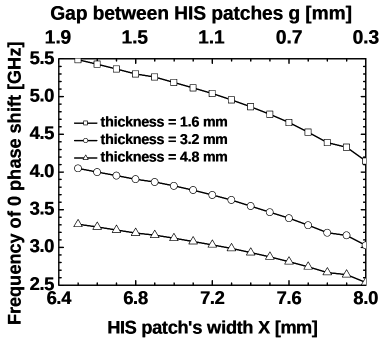

Fig. 5. Frequency for in-phase reflected wave in the function as HIS patch's width and gap between HIS patches.

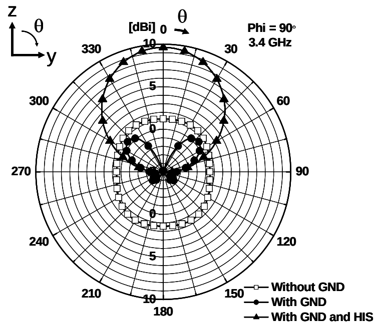

Fig.6.Effect of HIS and GND on directivity at 3.4 GHz

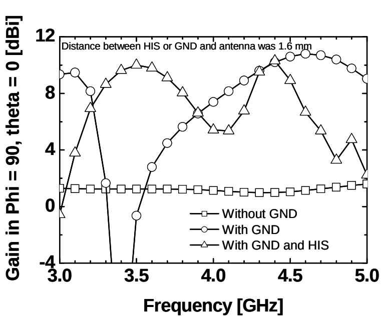

Fig. 7. Gain in the vertical direction versus frequency without GND, with GND and with GND and HIS of 15x15 patches. (X = 7.3 mm, g = 1 mm)

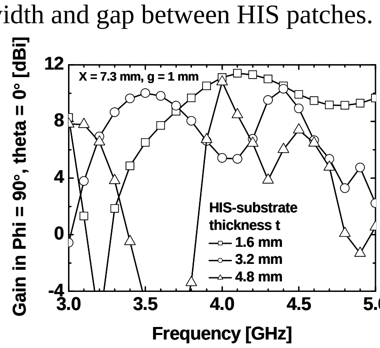

Fig. 8. Gain in the vertical direction versus frequency when HIS-substrate thickness were 1.6, 3.2 and 4.8 mm. (X = 7.3 mm, g = 1 mm)

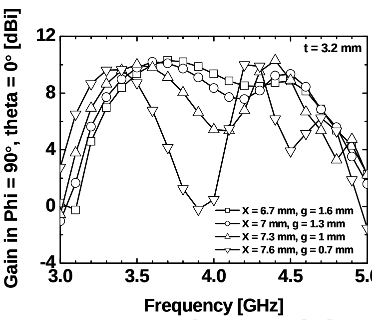

Fig. 9. Gain in the vertical direction versus frequency when patch's widths were 6.7, 7, 7.3 and 7.6 mm for HIS composed with 15x15 patches. (total size = 124.5x124.5 mm^2)

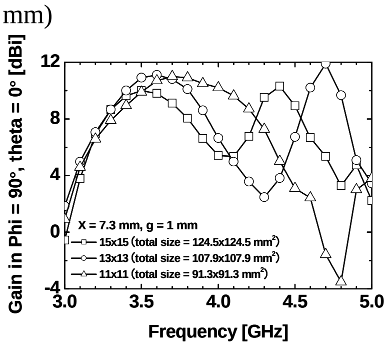

Fig. 10. Gain in the vertical direction versus frequency when the numbers of HIS patches were 15x15, 13x13 and 11x11. (X = 7.3 mm, g = 1 mm)

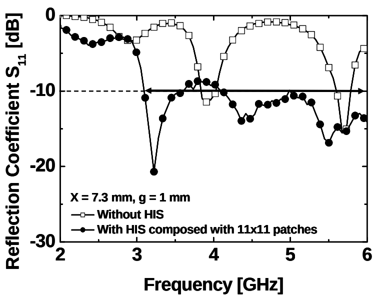

Fig. 11. Measured reflection coefficient S11 versus frequency for the antenna with HIS and without HIS of 11x11 patches. (X = 7.3 mm, g = 1 mm)

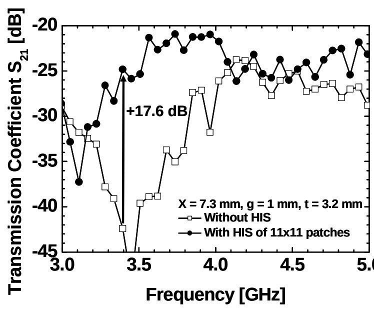

Fig. 12. Measured transmission coefficient S_{21} versus frequency for the antenna with and without HIS of 11x11 patches at the distance of 425 mm. (X = 7.3 mm, g = 1 mm)