Radiation Patterns and VSWRs of Handheld Devices in Several Real-Life Scenarios

Many books and brochures explain operation of handheld communication devices relying on free space antenna pattern. This kind of popular literature can be used as an initial source of information for understanding basic principles and explain simple facts about such devices. However, the experts in the field should be aware of more realistic radiation pattern, especially in urban environment where neighboring objects can cause significant reflections. There are also some critical situations that must be handled e.g., where a device should establish a connection in harsh conditions, or when maximum amount of EM\RF (electromagnetic\radio frequency) power has to be delivered to a receiver.

To better explain a distortion of the radiation pattern in different realistic scenarios, four examples will be discussed in this application note. The first scenario relates to a handheld device radiating in free space, the second scenario includes a handheld device operating above real ground, while the third and the fourth scenarios take into account the influence of a human operator. In general, the results of interest in all of the scenarios are a VSWR value and a radiation pattern.

The Model of The Handheld Device in Free Space

The model of the handheld device comprising a wire monopole antenna operating at 145 MHz and resting on the metallic box is shown in the Figure 1 with relevant dimensions outlined. The wire radius is 0.5 mm. As the monopole is shorter than quarter wavelength, a matching circuit must be used. The circuit is shown in Figure 1 with green hollow cylinder. The position of the device in the coordinate system corresponds to the approximate z-coordinate of the operator's mouth and chin.

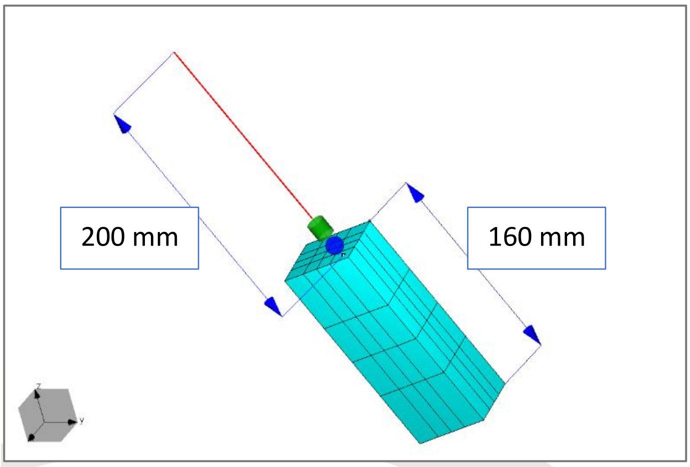

Figure 1. Handheld device in free space with dimensions

The VSWR of matched antenna and corresponding radiation pattern are shown in Figure 2. The radiation pattern is related to the realized gain as takes the antenna matching into the radiation pattern calculus.

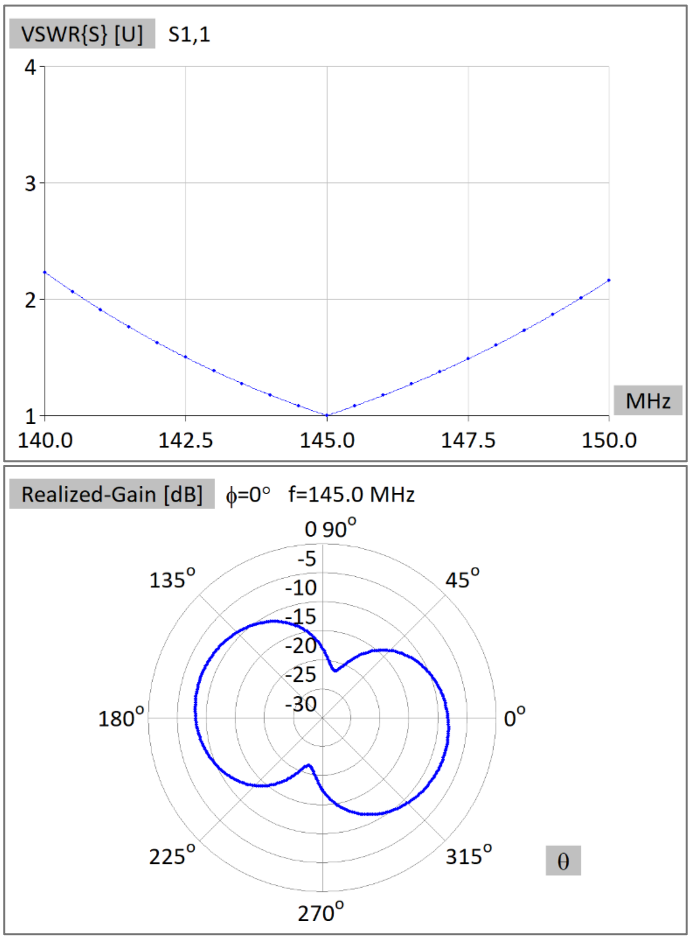

Figure 2. Handheld device in free space – VSWR (top) and radiation pattern at 145 MHz (bottom)

The Model of The Handheld Device Above Real Ground

The model of the handheld device above the real ground is again the one displayed in Figure 1. The only difference is in including WIPL-D real ground feature. Since handheld device is positioned relatively high above the real ground, a good accuracy can be obtained if one assumes that the real ground presence does not affect currents induced over the device, but only the radiation pattern. The parameters of the real ground are: $\varepsilon_{r\_real}=5$ and $\sigma=0.01$.

The comparison of the results when the handheld device radiates in the free space and when it radiates above real ground are presented in the Figure 3.

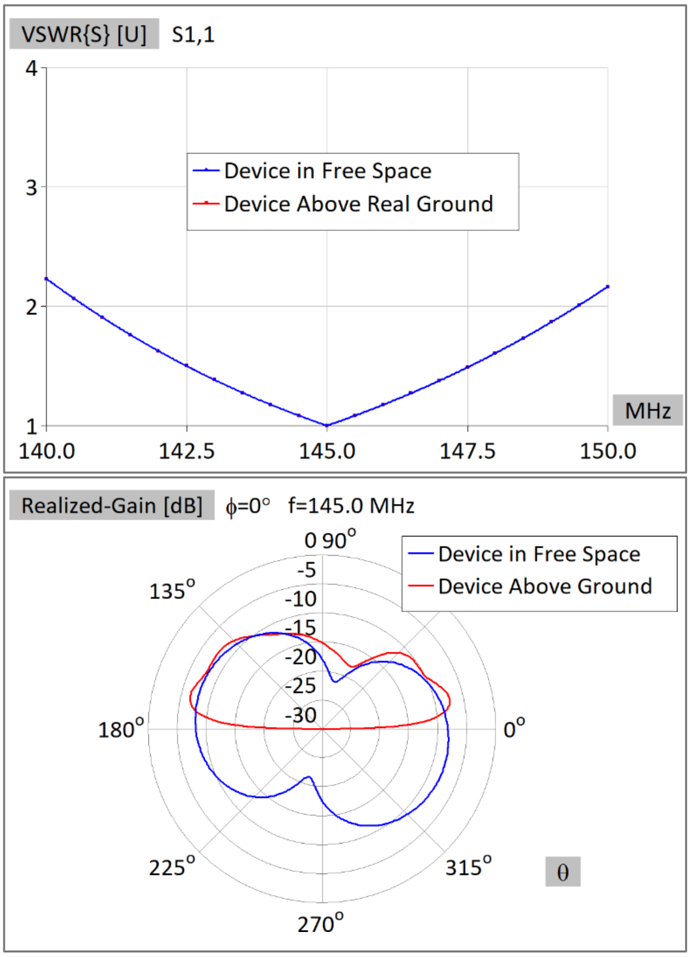

Figure 3. Handheld device - comparison of VSWRs (top) and radiation patterns at 145 MHz (bottom)

According to the results presented in Figure 3, the differences in VSWR values can be neglected which is a direct consequence of the fact that the influence of the real ground on the current distribution can be neglected. On the other hand, the presence of the real ground influences significantly the radiation pattern.

Two Models of The Handheld Device Above Real Ground in the Vicinity of a Human Operator

The next scenario considered includes a human operator of a handheld device introduced into EM model using a human body phantom as shown in Figure 4. The human body is modeled by using dielectric with parameters ε_{r_real}=35 and ε_{r_imag}=-13.83. Also, real ground is modeled so that it modifies only radiation pattern of the monopole and does not have any influence to the current distribution.

As an additional scenario, Figure 5 illustrates a similar case. Again, the device is placed in the hand of a human phantom and real ground is included. However, a piece of ground clump below the operator is added in order to study the influence of the real ground to the current distribution over the simulated structure.

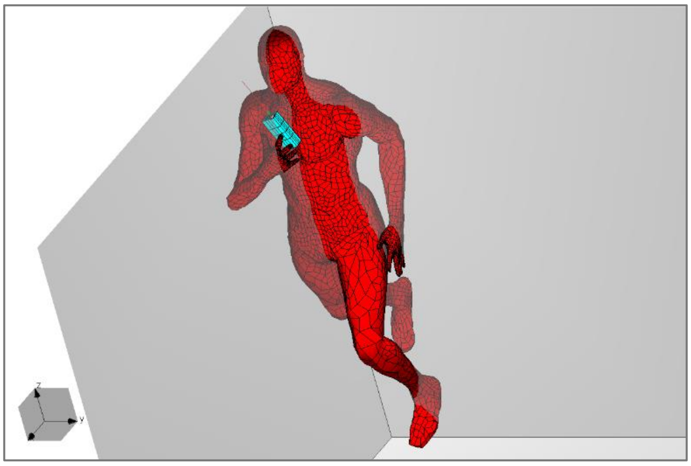

Figure 4. Handheld device above real ground carried by an operator

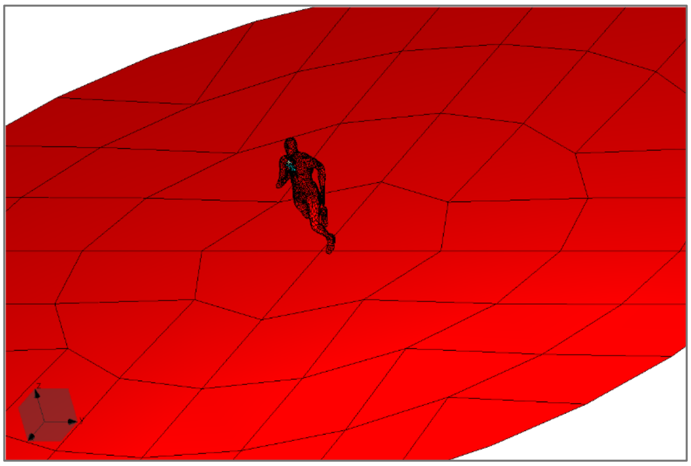

Figure 5. Handheld device above real ground modeled with clump carried by an operator

The results are outlined in the Figure 6. The top part of the Figure 6 displays a comparison of calculated VSWR for all four scenarios. Very important effect can be noticed in relation to the minimum values of VSWR. It can be seen that in the case where a device is placed in hand of human phantom, the minimum of the VSWR shifts downwards in frequency.

The bottom part of the Figure 6 displays radiation patterns calculated for all four scenarios. The difference between these results is noticeable. The presence of the real ground influences the radiation pattern. Furthermore, placing the device into human phantom's hand influences the radiation pattern even more. Finally, adding the clump does not have significant influence to radiation pattern.

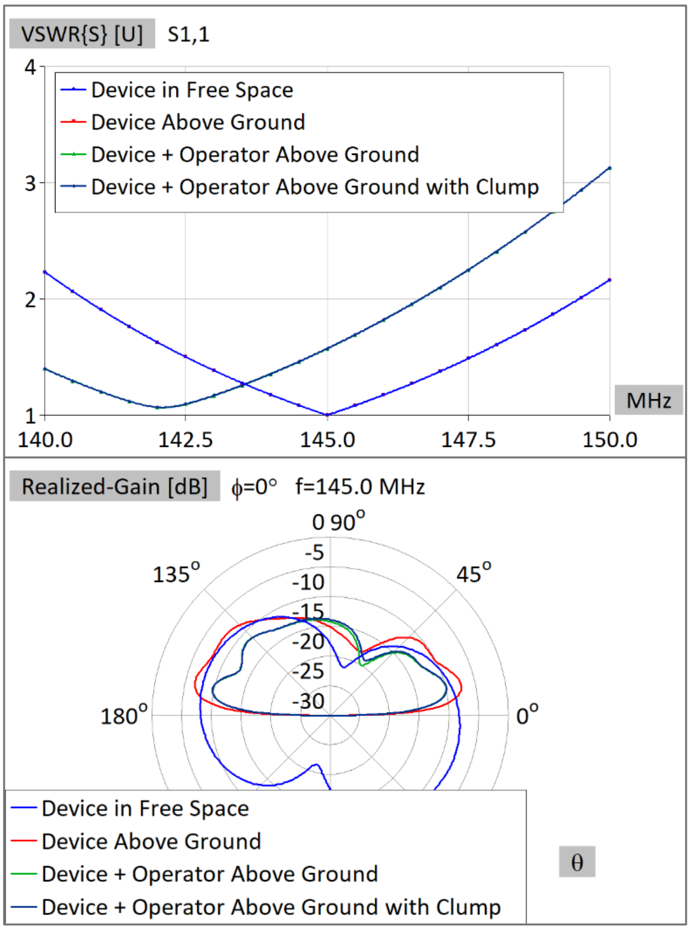

Figure 6. Handheld device in various environments – the comparison of VSWRs (top) and radiation patterns at 145 MHz (bottom)

Simulation Specifics

All the simulations are performed using the workstation outlined in the Table 1. Number of elements, number of unknowns, and total simulation time are given in Table 2. CPU is used for matrix elements testing. GPU is used for matrix inversion only in the scenarios: Handheld Device Above Real Ground in the Vicinity of an Operator and Handheld Device Above Real Ground with Clump in the Vicinity of an Operator.

Table 1. Workstation used for carrying the simulations

Hardware	Description
CPU	Intel® Core™ i7-7700 CPU @ 3.60GHz 3.60 GHz
RAM	64 GB
GPU	NVIDIA GeForce GTX 1080

Table 2. Models, number of elements, number of unknowns, and simulation time per frequency

Model	Number of Elements	Number of Unknowns	Simulation Time per Frequency
Handheld Device in Free Space	101	200	0.1 sec
Handheld Device Above Real Ground	101	200	0.1 sec
Handheld Device Above Real Ground in the Vicinity of an Operator	8,512	33,510	605.2 sec
Handheld Device Above Real Ground with Clump in the Vicinity of an Operator	8,576	39,366	619.1 sec

Conclusion

Four scenarios encompassing handheld communication device in various real-life environments are discussed. In all the scenarios, results of interest are VSWR and radiation pattern presented using absolute gain.

For the model of the device resting in operator's hands, the minimum of the VSWR is shifted downwards in frequency. Thus, it can be claimed that presence of operator working with the device results in a different current distribution comparing to the scenarios without the human involved.

The presence of the real ground influences the radiation pattern comparing to the handheld device in free space, while placing the device into human phantom's hand influences the radiation pattern even more, but adding the clump in the last instance does not have significant influence to the radiation pattern.

It can be also concluded that although VSWR minimum is shifted when modeling the influence of an operator, realized gain in all three scenarios, which include a ground plane, does not vary significantly. This can be explained with low values of VSWR, below 2.0.

All the simulations were performed in reasonable amount of time using an affordable computer workstation.