Delft University of Technology

Spectral Domain Methods In Electromagnetics

EE4620

Assignment 3: Surface Wave Characterisation

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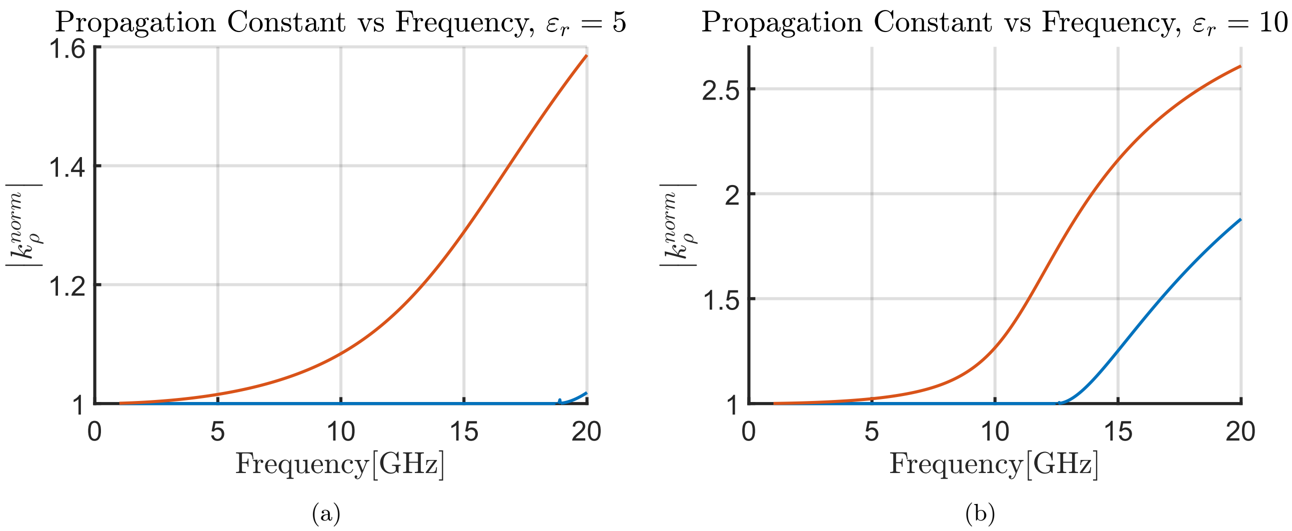


Figure 1: Propagating modes with increasing frequency.Orange line represents TM0 and blue line represents TE1.

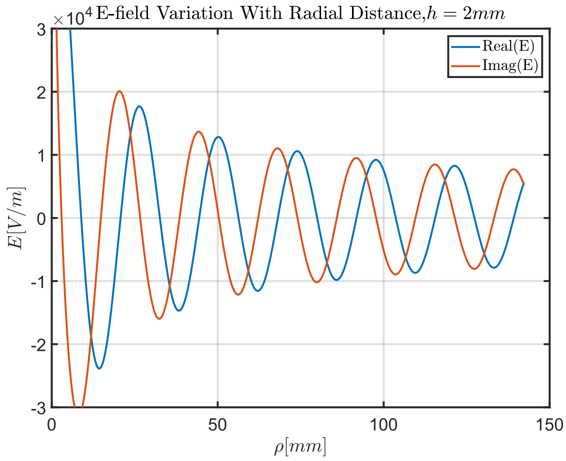
Question 1

In this part of the assignment, surface wave modes propagating in grounded slab have been plotted by sweeping frequency from 1 GHz to 20 GHz with two different dielectrics one with $\varepsilon_r = 5$ and other with 10. The two plots are given in figure 2.

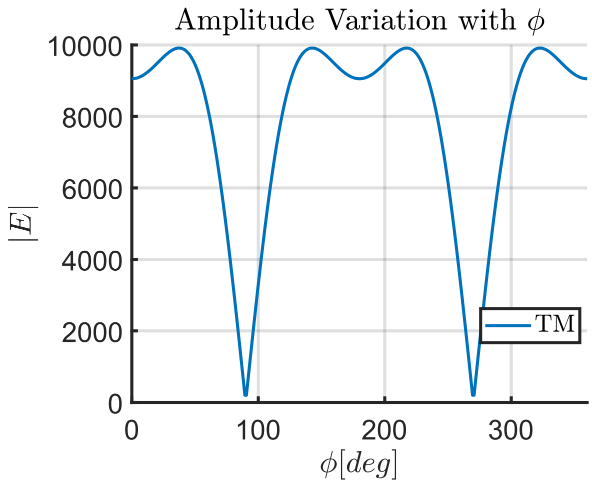
At each frequency, the propagation constant of the surface wave is calculated by using the Newton-Raphson method and the dispersion equation given in [1]. The dispersion equation is solved for both TE and TM waves. As shown in figure 1a at $\varepsilon_r = 5$ the TE1 mode surface wave only starts propagating around 19 GHz. And at 20 GHz it reaches a maximum propagation constant of 1.01 which is very small relative to the TM0 but when the other dielectric is used the TE1 mode starts to propagate at a lower frequency around 13 GHz and as frequency increases to 20 GHz normalised propagation constant reaches a much higher normalised propagation constant value of 1.88 1b.
Looking at the figure 1a the propagation of the TM0 mode starts around 3.1 GHz with a normalised propagation constant of 1.01 and reaches a maximum of 1.58 at 20 GHz. The plot in figure 1b mode TM0 with dielectric $\varepsilon_r = 10$ the propagation starts around 4.3 GHz with a normalised propagation constant of 1.01 and reaches a maximum of 2.61 at 20 GHz.

Question 2

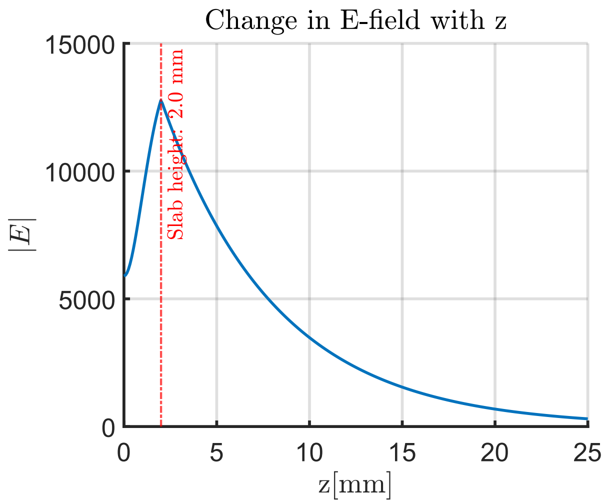
In this part strength of the surface wave has been analysed at different parts of the grounded slab. First at $\phi = 0°$ and at 2 mm the change in the real and imaginary part of the electric field strength has been analysed with increasing radial distance from the source. As shown in the plot 2a with increasing ρ the field strength decreases, another observation is that there is a phase shift of 90° between the real and imaginary part of the field strength.



(a)



(b)



(c)

Figure 2: Change in the E-field strength at different observation points

Secondly, the TM0 field strength from $\phi = 0°$ to $360°$ has been analysed by fixing $\rho = 150\,\text{mm}$. The result is given in figure 2b. As shown on the plot the field has two nulls one at $\phi = 90.6\,°]andanotherat201.5°$. Finally by fixing $\phi = 0°$ and $\rho = 150\,\text{mm}$ the z is swept from $0\,\text{mm}$ to $25\,\text{mm}$. As seen on figure 2c the field reaches its maximum at $\text{z} = 2\,\text{mm}$ and decreases exponentially outside the slab as z increases. The reason for the increase until the slab-dielectric interface is that the source is present at that interface and since the incident angle of the surface wave is larger than the critical angle the field decays exponentially outside the slab.

Question 3

This section will discuss how presence of the surface wave reduces the efficiency of the grounded slab antenna.

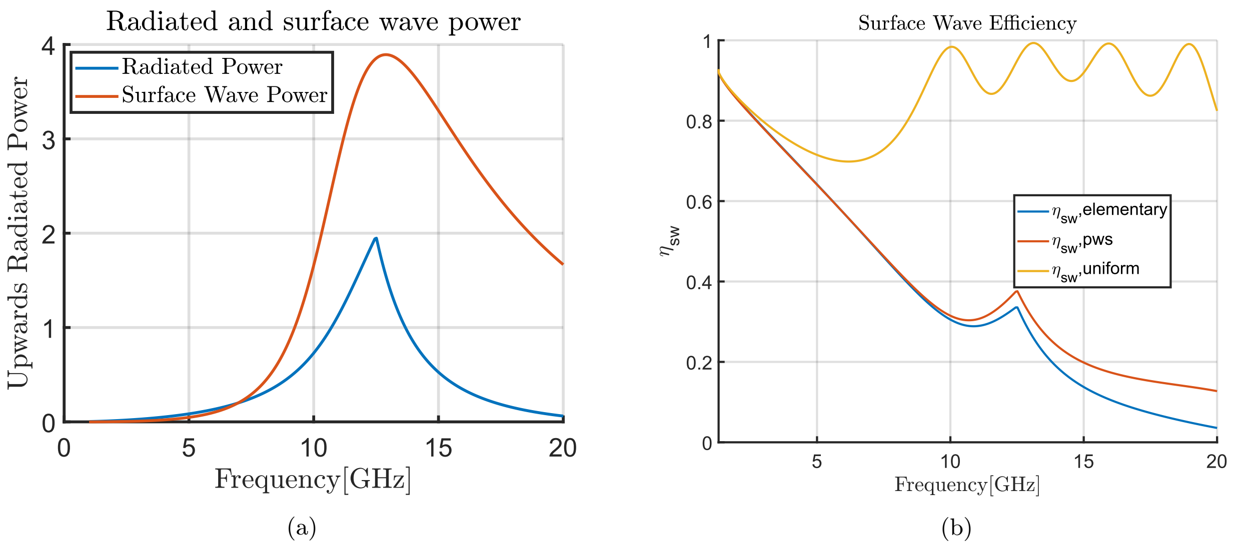


Figure 3: Radiated and surface wave power(normalised to power from free space dipole) from an elementary electric current source in figure 3a and surface wave efficiencies from different current distributions given in 3b.

As shown in the figure 3a after 6.97 GHz the surface wave power is larger than the radiated power. And at a frequency around 12.5 GHz both radiated power and surface wave power reach their maximum; radiated power is 1.95 at maximum and surface wave power is 3.9 so surface wave power is double the radiated power.
In figure 3b surface wave efficiency results for three different current distributions have been plotted against frequency. The equation 1[1] is used to obtain the figure shown. For both elementary and pws source distributions the efficiency decreases with increasing frequency except at 12.5 GHz. However uniform current distribution first decreases and then starts to oscillate, looking into this figure at certain frequencies uniform current distribution does not support surface waves so it could be used to prevent surface waves.

$$\eta_{sw} = \frac{P_{rad}}{P_{rad} + P_{sw}} \tag{1}$$

References

A. Laguna, “EE4620 Assignment 3 Instruction Lecture: Surface Wave Characterisation.”