Strip Lines on the Cylindrical Dielectric Substrate

Žaklina J. Mančić[1], Saša S. Ilić[2] and Slavoljub R. Aleksić[3]

***Abstract* – The paper presents quasi TEM analysis of strip lines on the cylindrical substrate, when the strip is of a negligible thickness or has some final thickness. As a calculation method Equivalent Electrode Method was used, as well as the Finite Elements Method (FEM). The obtained results are shown in tables and graphs. It has been noted that the results correspond well using these two methods.**

***Keywords* – strip lines, quasi-TEM analysis, Equivalent Electrode Method (EEM), Finite Elements Method (FEM), Green functions.**

I. INTRODUCTION

Strip lines of usual rectangular geometry are widely used [19-20]. With them the characteristic impedance and relative dielectric permittivity depend on geometry and line dimensions. Using EEM, the strip line with cylindrical isotropic substrate, Fig.1, was calculated, and its characteristics were analysed.

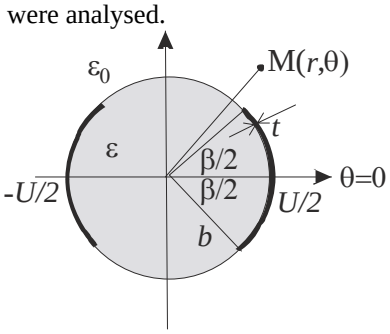

Fig. 1. Strip line on cylindrical substrate.

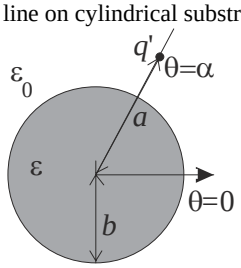

Fig. 2. Charge per unit length outside dielectric cylinder.

As EEM requires knowledge of Green function, Green function has been used [24] for charge per unit length in the proximity of dielectric cylinder, Fig.2:

$$\varphi = \begin{cases} \varphi_0 - \dfrac{q'}{2\pi(\varepsilon+\varepsilon_0)} \ln\left[1 - 2\dfrac{r}{a}\cos(\theta-\alpha) + \left(\dfrac{r}{a}\right)^2\right], & r \le b \\ \varphi_0 - \dfrac{q'}{4\pi\varepsilon} \ln\left[1 - 2\dfrac{r}{a}\cos(\theta-\alpha) + \left(\dfrac{r}{a}\right)^2\right] \\ -\dfrac{q'}{4\pi\varepsilon}\dfrac{\varepsilon_0-\varepsilon}{\varepsilon+\varepsilon_0} \ln\left[1 - 2\dfrac{b^2}{ar}\cos(\theta-\alpha) + \dfrac{b^4}{a^2r^2}\right], & r > b \end{cases} \quad (1)$$

where φ_0 is a constant dependent of the referential point choice. Equations (1) allow determination of expressions for electrical field components in a cylindrical coordinate system, for $r > b$:

$$E_r = \frac{1}{2\pi\varepsilon_0}\left(A + \frac{\varepsilon_0-\varepsilon}{\varepsilon_0+\varepsilon}B\right), \quad E_\theta = \frac{1}{2\pi\varepsilon_0}\left(C + \frac{\varepsilon_0-\varepsilon}{\varepsilon_0+\varepsilon}D\right) \quad (2)$$

where:

$$A = \frac{r - a\cos(\theta-\alpha)}{a^2 - 2ar\cos(\theta-\alpha) + r^2},$$

$$B = \frac{arb^2\cos(\theta-\alpha) - b^4}{a^2r^3 - 2ar^2b^2\cos(\theta-\alpha) + b^4 r},$$

$$C = \frac{a\sin(\theta-\alpha)}{a^2 - 2ar\cos(\theta-\alpha) + r^2},$$

$$D = \frac{b^2 a\sin(\theta-\alpha)}{a^2r^2 - 2arb^2\cos(\theta-\alpha) + b^4}.$$

Relative error given in Table 1 was calculated using formula:

$$\delta[\%] = \frac{\left|Z_c^{EEM} - Z_c^{FEM}\right|}{Z_c^{FEM}} \cdot 100, \quad (3)$$

where characteristic impedance, as well as effective dielectric permittivity are defined in a standard way, that is, $Z_c = Z_{c0} \Big/ \sqrt{\varepsilon_r^{eff}}$, $\varepsilon_r^{eff} = C'/C_0'$, where C_0' and Z_{c0} are parameters obtained for the case when $\varepsilon = \varepsilon_0$.

[1]Žaklina J. Mancic is with the Faculty of Electronic Engineering, University of Niš, Aleksandra Medvedeva 14, 18000 Nis, Serbia, E-mail: zmancic@elfak.ni.ac.yu

[2]Saša Ilić is with the Faculty of Electronic Engineering, University of Niš, Aleksandra Medvedeva 14, 18000 Nis, Serbia, E-mail: silic@elfak.ni.ac.yu

[3]Slavoljub R. Aleksić is with the Faculty of Electronic Engineering, University of Niš, Aleksandra Medvedeva 14, 18000 Nis, Serbia, E-mail: as@elfak.ni.ac.yu

II. RESULTS

Cylindrical strip line was analysed, of *b* radius with symetrically laid strip conductors, Fig.1. An angle at which the strip can be seen from the center of dielectric cylinder is β, while in the most general case the strip thickness is marked with *t*. The obtained results were compared with the results gained by using program package FEMM [13]. The results of comparison are shown in Table 1, for $\varepsilon_r = 2.2$, different ratio t/b and different values of the angle β.

TABLE I
COMPARISON OF RESULTS OBTAINED WITH EEM AND FEM TECHIQUE

$t/b = 0$				
β[deg]	30	60	90	120
$Z_c^{EEM}[\Omega]$	257.89	190.58	148.99	116.43
$Z_c^{FEM}[\Omega]$	256.50	189.76	148.59	115.94
δ[%]	0.54	0.43	0.27	0.42
ε_r^{eff} (EEM)	1.600	1.600	1.599	1.600
ε_r^{eff} (FEM)	1.600	1.599	1.601	1.601
$t/b = 0.01$				
β[deg]	30	60	90	120
$Z_c^{EEM}[\Omega]$	254.20	188.44	147.46	115.17
$Z_c^{FEM}[\Omega]$	253.34	187.96	147.23	115.01
δ[%]	0.34	0.26	0.16	0.14
ε_r^{eff} (EEM)	1.590	1.592	1.593	1.592
ε_r^{eff} (FEM)	1.591	1.593	1.593	1.593
$t/b = 0.05$				
β[deg]	30	60	90	120
$Z_c^{EEM}[\Omega]$	244.25	182.77	143.23	111.64
$Z_c^{FEM}[\Omega]$	243.91	182.42	142.91	111.35
δ[%]	0.14	0.19	0.22	0.26
ε_r^{eff} (EEM)	1.566	1.573	1.574	1.572
ε_r^{eff} (FEM)	1.567	1.574	1.575	1.573
$t/b = 0.1$				
β[deg]	30	60	90	120
$Z_c^{EEM}[\Omega]$	235.29	177.27	139.10	108.14
$Z_c^{FEM}[\Omega]$	235.15	177.01	138.85	107.91
δ[%]	0.06	0.15	0.18	0.21
ε_r^{eff} (EEM)	1.544	1.554	1.556	1.552
ε_r^{eff} (FEM)	1.546	1.555	1.557	1.553

Fig. 3 shows characteristic impedance in the function of angle β, where the relative dielectric permittivity is ε_r, and $t/b = 0$. Fig. 4 shows characteristic impedance in the function of strip thickness and cylinder radius ratio, for $\varepsilon_r = 2.2$ where β is parameter.

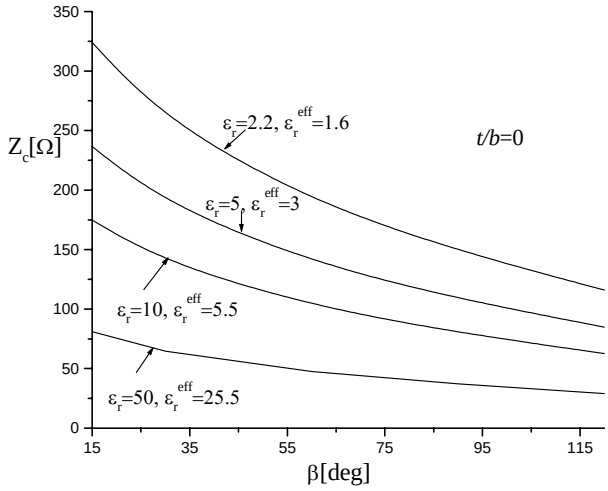

Fig.3. Characteristic impedance in the function of angle β.

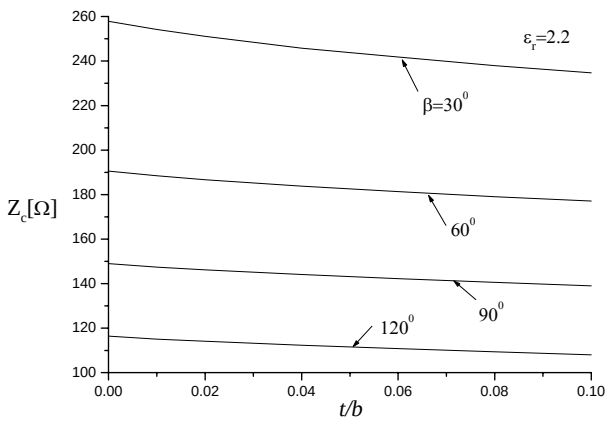

Fig.4. Characteristic impedance in the function of thickness strip, β is the parameter

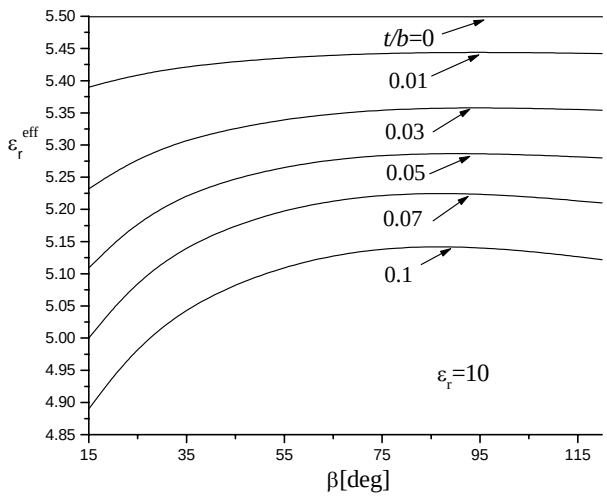

Fig.5. Relative effective dielectric permittivity in function of angle β, conducting strip thickness is the parameter.

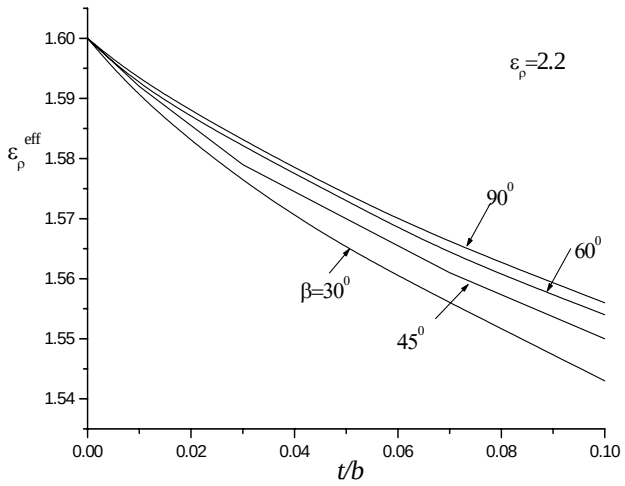

Fig. 6. Relative effective dielectric permittivity in the function of conductive strip thickness for various values of angle β.

The ratio of electrical field intensity in the function of distance from the cylinder center, E, and field intensity on the cylinder surface, E_0, for various directions $(r > b,\ \theta)$, where t/b is parameter, is shown in figures 8, 9 i 10. They illustrate that a large amount of energy is concentrated within dielectric substrate, and with the distance twice larger than cylinder radius, the field is negligible. A conclusion can be drawn from this, that with these lines it is desirable that relative dielectric substrate constant is as large as possible, so that the largest amount of energy is in it.

III. Conclusion

One type of strip lines has been calculated, both of negligible thickness and of final thickness, on a cylindrical substrate. The calculations have showed that in the case of disregarding strip thickness for the required dielectric cylinder constant, these lines have practically constantly effective dielectric constant, independent of line dimensions. This result is actually, the expected theoretical result, that the effective dielectric permittivity is actually equal to arithmetic mean of relative dielectric constant for air and relative dielectric substrate constant. This characteristic, as well as small dissipation of electrical field outside the line, could be an advantage over up to now used strip lines on the substrate of rectangular cross-section. Also, it should be said that the program developed in FORTRAN is much faster that FEMM program. Namely, the calculations were done on PENTIUM 3 (900 MHz) computer with 256 MB RAM, and the duration of calculating using EEM (600 electrodes) was about 30 seconds, while with 500000 final elements, it lasted for 8 minutes.

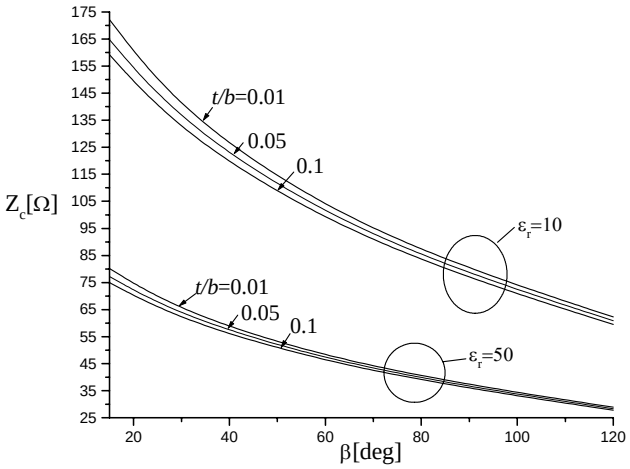

Fig.7. Characteristic impedance in the function of angle β for various thickness of conductive strips.

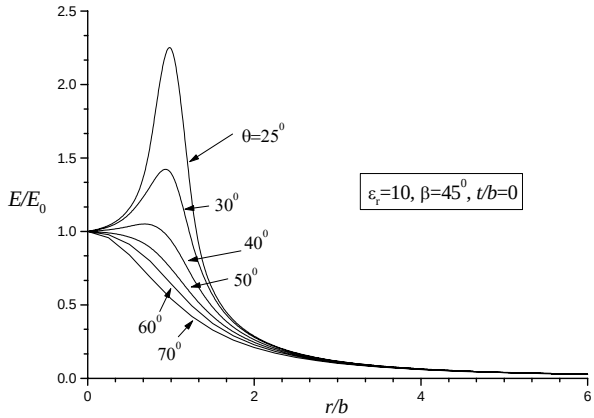

Fig.8. Field intensity in the function of distance for strips of negligible thickness and $\varepsilon_r = 10$.

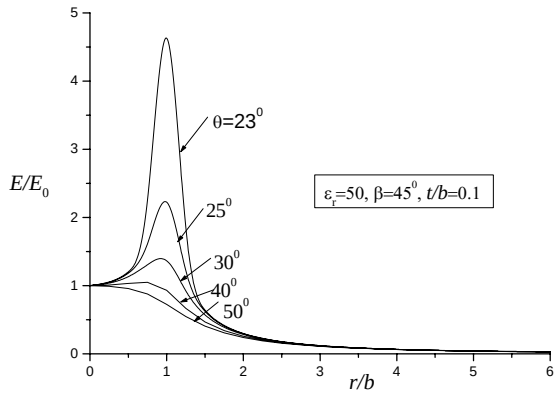

Fig.9. Field intensity in the function of distance for strips of final thickness and $\varepsilon_r = 50$.

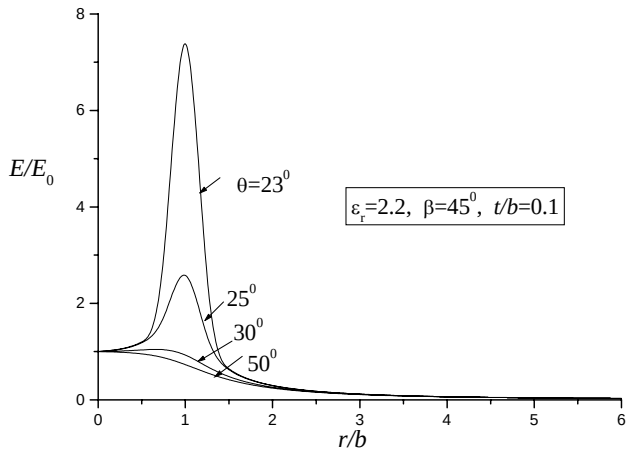

Fig. 10. Field intensity in the function of distance for final thickness strips and $\varepsilon_r = 2.2$.

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