*URSI GASS 2020, Rome, Italy, 29 August - 5 September 2020*

# Investigation of Horn Launchers for Surface Wave Transmission Lines

Ergin Dinc*, Eloy de Lera Acedo
Cavendish Laboratory, University of Cambridge, UK, CB3 0HE

The principal Transverse Magnetic (TM) mode on dielectric coated wires can be used for high-capacity backhaul connectivity over the existing copper infrastructure. Non-radiating TM mode along a dielectric coated wire was first studied by Goubau [1]. Dielectric coated wire acts like an open waveguide and provides low attenuation even at millimetre and terahertz frequencies. Although surface wave (SW) transmission lines were proposed in 50s, investigation and optimisation of SW launchers stand as an open research problem. In the literature, the most common type of SW launcher is in the form of horn, i.e., a coaxial line with tapered outer conductor as in Figure 1(a). Hence, the main objective of this paper is to investigate excitation of SWs by using horn launchers.

Transmission and reception efficiency of SW launchers are dominated by two factors: (1) *radius of horn launcher,* and (2) *coupling efficiency of launcher modes*. The former is related to the percentage of SW power ($N(R)$) propagated within the radius of horn launcher $R$, and this loss can be calculated by using the theory in [1]. For the latter, the narrow-end of the launcher is excited with a TEM wave, but TEM wave can couple to other propagating modes inside the launcher. By considering the symmetry and polarisation of the fields, TEM mode can only couple with azimuthally symmetric TM modes ($\mathrm{TM}_{0n}$). Power of the launcher modes can be calculated with the coupling coefficients derived in [2], and the transverse fields at the wide-end of the launcher can be written as the summation of all the existing modes: $E_t = \sum_{\tau=0}^{n} V_\tau \overline{e_t}_\tau = V_{SW}\overline{e_t}_{SW} + V_U \overline{e_t}_U$, and $H_t = \sum_{\tau=0}^{n} I_\tau \overline{h_t}_\tau = I_{SW}\overline{h_t}_{SW} + H_U \overline{h_t}_U$, where $\overline{e_t}_\tau$ and $\overline{h_t}_\tau$ are the orthonormal set of field vectors for TEM ($\tau = 0$) and TM ($\tau \geq 1$) modes propagating inside the horn launcher. $\overline{e_t}_{SW}$ and $\overline{e_t}_U$ represent the normalised fields for the SW mode and any unknown radiating mode at the cross section, respectively. Coupled power to the SW mode can be estimated by multiplying the transverse fields by the normalised SW fields and integrating over the cross section, and is formulated as

$$P_{SW} = \Re(V_{SW} I_{SW}^{\ *}) = \left(\sum_{\tau=0}^{n} V_\tau \int\int_{S_0} \overline{e_t}_\tau \cdot \overline{e_t}_{SW}^{\ *} dS\right)\left(\sum_{\tau=0}^{n} I_\tau \int\int_{S_0} \overline{e_t}_\tau \cdot \overline{e_t}_{SW}^{\ *} dS\right)^{*}. \tag{1}$$

Figure 1(b) includes the CST simulation and theoretical results ($S_{21} = 10\log(P_{SW}) + 10\log(N(R)/100)$) for a 0.6m SW transmission line with 1mm conductor radius and 1mm dielectric thickness ($\varepsilon = 3.6$). Horn launchers with different radii are designed based on the Dolph-Tchebycheff transmission-line taper in order to reduce the reflection loss. As noticed, the theoretical curves are consistent with the numerical simulations. 20mm radius provides approximately 2GHz of nearly flat bandwidth between $7.8-9.8$GHz.

(a) (b)

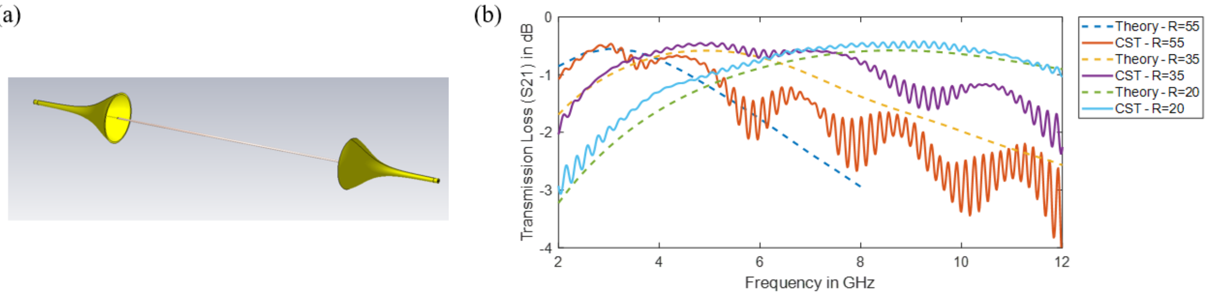


**Figure 1.** (a) SW transmission line, (b) Transmission loss results for the SW transmission line.

## References

[1] G. Goubau, "Surface waves and their application to transmission lines," *Journal of Applied Physics*, **21**, 1950, pp. 1119–1128, doi: 10.1063/1.1699553.

[2] J. Shafii, R. J. Vernon, "Mode coupling in coaxial waveguides with varying-radius center and outer conductors," *IEEE Trans. Microw. Theory Techn.*, **43**, vol. 3, 1995, pp.582–591, doi: 10.1109/22.372104.