Bidirectionality in Reciprocal and Non-reciprocal Waveguides

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In 1958 (R.F. Harrington and A.T. Villeneuve, IRE Trans. MTT, 7, 441-446, 1959) discussed for the first time the issue of bidirectionality in waveguides. Bidirectionality means that for each eigenmode propagating in one direction in the waveguide there exists an eigenmode propagating in the opposite direction with the same phase velocity. For a waveguide filled with isotropic material this is trivial but for waveguides filled with anisotropic or even bianisotropic media this becomes less evident. Harrington and Villeneuve provide a proof, based on a circuit interpretation, that waveguides filled with reciprocal materials are always bidirectional. In 1991 (P.R. McIsaac, IEEE Trans. MTT, 39, 1808-1816, 1991) shows that waveguides can be bidirecitional if their geometry and material parameters satisfy certain symmetries. However, it is mentioned that a reciprocal waveguide is not always bidirectional. In 1996 (F. Olyslager, IEEE Trans. MTT, 2064-2074, 1996) provides a proof based on solely using the Lorentz reciprocity theorem that Harrington and Villeneuve were right. In 2004 (D. Pissoort and F. Olyslager, IEEE Trans. MTT, 542-553, 2004) this proof was extended to periodic waveguide structures. Recently, in 2006, (A.D. Yaghjian, Proc. Natl. Radio Sci. Meeting, Boulder, CO, 33, 2006), another independent proof was provided using an excitation by antennas and using the reciprocity in an antenna system. This led to a critical study of the proof from 1996 and allowed us to refine it somewhat such that it is more robust.

Despite numerous numerical simulations and measurements on complex waveguiding structures in literature the author is not aware of any such experiment contradicting the claims by Harrington and Villeneuve.

In this contribution the new extended proof will be presented, carefully discussing weak and strong points of this and other proofs. We will also discuss what happens in non-reciprocal waveguides, which also can bi-directional if certain conditions are met.