An Initial Study on Using Carbon Microfiber Transmission Lines in Conformal Array Networks

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***Abstract*—In this paper, an initial study on the possible use of carbon microfibers as a transmission line (TL) feed network in conformal microstrip antenna arrays was conducted. Initially, a 12.0 cm long 50 Ω microfiber transmission line was manufactured and the wave propagation properties were measured. These characteristics were then compared to the propagation properties of a traditional copper microstrip TL with the same length. Once these propagation characteristics were determined, two parallel TLs with a separation of 4.0 mm were then manufactured to investigate the unwanted coupling that may occur in a feed network of an array. One of these TLs was a copper microstrip line and one was a microfiber TL with similar dimensions. Overall, it has been shown that the microfiber TLs support wave propagation in a manner similar to the copper microstrip TLs but the attenuation constant was larger, as the 3 dB point was at 2.5 GHz. Also it was evident from the measurements that the microfiber TLs were more immune to coupling at high frequencies. The results demonstrated that these properties made microfiber TLs a good possible candidate for the feed network of a conformal microstrip antenna array.**

***Index Terms*—Carbon microfibers, feed network and arrays.**

I. Introduction

Copper microstrip TLs have been used extensively in the design of feed networks for microstrip antenna arrays [1]-[4]. However, one drawback of arrays with large feed networks is that the gain and efficiency can be reduced by the coupling in the feed network [1]. Furthermore, the radiation from the feed network can be significant and have a noticeable effect on the array radiation pattern, as reported in [2].

In this work, the first steps on the possibility of reducing the radiation loss and mutual coupling of a feed network with a carbon microfiber TL-based design for arrays is presented. The carbon microfibers have been first introduced and investigated as a transmission line in [5]; however, the mutual coupling with copper microstrip and microfiber TLs has not been studied. It was shown that the microfibers in this work can be used to design a TL for a feed network with useful matching, reduced radiation and lower coupling with other interconnects, making it a good candidate for feed networks.

II. The Prototype Microfiber Transmission Line

To investigate the properties of a microfiber TL in a feed network of an array, several prototype TLs were manufactured. Initially, the known 50 Ω copper microstrip TL shown in Fig.

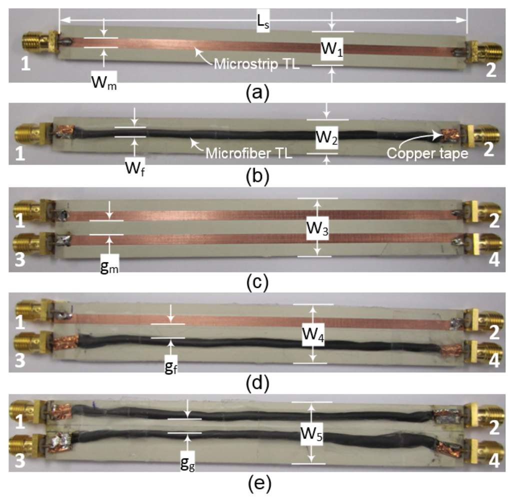

Fig. 1. Fabricated microstrip and microfibers transmission lines. (a) Microstrip TL only. (b) Carbon microfiber TL only. (c) Two microstrip TLs. (d) A microstrip and microfiber TL. (e) Two microfiber TLs. Structure characteristics: L_s=120 mm, $W_1 = W_2$=12.86 mm, $W_3 = W_4 = W_5$=15.72 mm, $W_m = W_f$=2.86 mm, $g_m = g_f = g_g$=4 mm.

1(a) was manufactured on a TMM4 substrate (ε = 4.5, tan δ= 0.0020 and thickness, T_s = 1.52 mm) with a copper ground plane on the bottom and a length of 12.0 cm. Then, the microfiber TL shown in Fig. 1(b) was manufactured on the same TMM4 substrate as the copper TL and similar dimensions. The flexible bundle of microfibers was manufactured by Fibre Glast [6]. Next, the coupled TLs in Figs. 1(c)-(e) were manufactured with an approximate spacing of 4.0 mm. The problem in Fig. 1(c) investigated the coupling between two coppper TLs; the problem in Fig. 1(d) investigated the coupling between a copper and microfiber TL and the problem in Fig. 1(e) studied the coupling between two microfiber TLs. The microfiber TLs were manufactured by twisting the fiber bundles and fed from the edge with a SMA connector. The bundles were connected to the center pin of the SMA connector with 1.0 oz adhesive copper tape, as shown in Fig. 1(b). Enough carbon microfibers were bundled together to achieve a characteristic impedance of Z_o = 50Ω for all TLs.

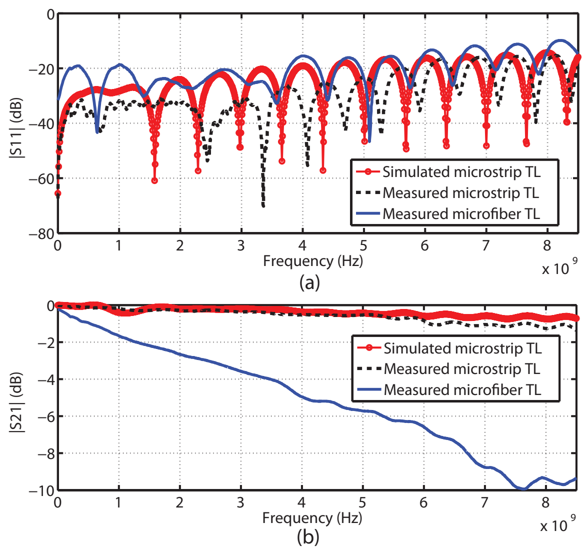

Fig. 2. Simulated and measured magnitude of (a) S_{11} and (b) S_{21}, of the microstrip and microfiber TLs.

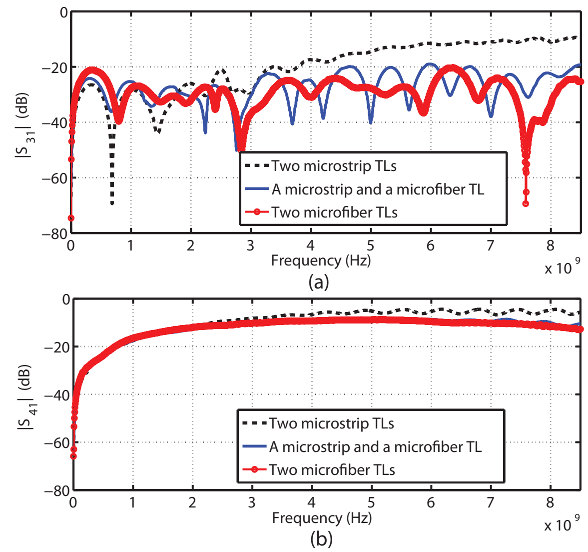

Fig. 3. Magnitude of (a) $|S_{31}|$ (Near end coupling) and (b) $|S_{41}|$ (Far end coupling) from measurements.

III. Measurement and Simulation Results

Agilent's full-wave simulation tool, Advanced Design System (2013), was used to model the uncoupled fabricated copper microstrip TL in Fig. 1(a) and the results are shown and compared with measurements in Fig. 2. The S-parameters were measured using a calibrated Agilent network analyzer, E5071C. Next, for comparison the S-parameters for the microfiber TL in Fig. 1(b) were measured and compared to the copper TL in Fig. 2. Overall, good agreement between the $|S_{11}|$ values can be observed; however, the $|S_{21}|$ values show more loss in the microfiber TL. Then, to investigate the unintentional coupling between the microstrip and the microfiber TLs, the coupled TLs in Figs. 1(c)-(e) were measured with the Agilent network analyzer. These results are shown in Fig. 3. The near-end coupling was measured between ports 3 and 1, while the far-end coupling was measured for the same set of TLs between port 4 and 1. It should be noted that all the ports not used for the measurements were terminated with a 50Ω load.

IV. Discussion

The results shown in Fig. 2 demonstrate the wave propagation of the microfiber TLs. It has been shown that matching can be achieved, and for frequencies below 2.5 GHz, the attenuation constant of the microfiber TL may be suitable for some applications. Furthermore, the results in Fig. 3 show that the coupling of the microfiber TLs are 10 dB lower in some bands. Finally, it should be noted that the resistance of the fabricated microstrip and microfiber TLs, as shown in Fig. 1(a) and (b), has been measured using an Agilent LCR meter, U1732C and found to be 6.6 mΩ/cm and 232.1mΩ/cm, respectively. The proposed work can now be extended to explore the usefulness of the microfiber TLs in a practical microstrip antenna array with a complex feed network.

V. Conclusion

In this paper, several transmission line (TL) network prototypes consisting of copper and microfiber bundles with a length of 12.0 cm have been simulated, manufactured and tested. Initially, the propagation characteristics of the microfiber TL were compared to a copper TL and it was shown that fair propagation up to 2.5 GHz could be achieved. Then, to study the behavior of the microfiber TL in the presence of other conductors, as in a feed network, various coupled TL prototypes were manufactured and tested with a spacing of approximately 4.0 mm. It has been shown that the coupling effect between the microfiber and the copper TLs was approximately the same up to 3 GHz, but the coupling to the microfiber TLs was up to 10 dB lower at the higher frequencies. The microfiber TL is hence proposed as an alternative for the feed network of a microstrip antenna array as it has better coupling immunity at high frequencies with lower radiating properties.

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