Printed Feed Network on a Single Surface for Dual Polarized Antenna Array

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***Abstract*—A simplified packaged microstrip line (MSL) feeding network on a single surface for a dual-polarized array is presented. The MSL couples to a cross-slot-aperture of the antenna elements. A dual-polarized magneto-electric dipole is designed with two different types of feedlines. A Ka-band 4 x 4 dual-polarized array is designed. The array has better than 16 dBi gain with port isolation better than 30 dB and cross-polarization better that -20 dB within a 20% bandwidth. The presented feed scheme is valid for any dual-polarized array size.**

I. Introduction

In the past, directional radiation has been extensively exploited for detection, ranging and satellite communication. However, with the advent of millimeter-wave (mm-Wave) for 5G communication, higher-order array implementation is necessary to counter path loss through high gain. Furthermore, a need for device miniaturization and high throughput of the wireless link are also desired. Dual polarized (dual-pol) antenna arrays, with shared single-cross-slot-aperture (SCSA) elements, designed on printed circuit board are attractive choices [1], [2]. In this regard, MSL feed-networks are conventionally implemented on separate layers to have high ports' isolation. This could result in unequal aperture coupling, and difficulties with multi-layer feed implementation as PMC packaging of the MSLs are also required at mm-Wave [3], [4]. The implementation of MSL array feed-network topologies on a single surface, and associated performance effects in an array environment, are presented here. By using the proposed feeding mechanism, the isolation and cross-polarization (x-pol) performance of a magneto-electric dipole (ME-dipole) as a single element and within a 4×4 array are analyzed.

II. MSL Feed-Network on a Single Surface

Starting with a 2×2 array, as illustrated in Fig. 1(a), the feeding network can be designed either on a two-layer or single layer. Whereas, in Fig. 1(b), it is shown that a planar crossover [4] can be used to implement it on a single surface, exclusively. However, in both cases (a, b), if it is designed on a single surface, then SCSA excitation feedlines need to be designed carefully. For the case of multi-layer implementation, the shared aperture could be excited with two similar feedlines. However, in the case of single surface implementation, it must require two different feed mechanisms such as a fork- and a hook-shaped MSL aperture excitation to avoid crossover/bridge. Furthermore, for the array-order higher than 2×2, the crossover based single surface feed-network would not be a pragmatic mm-Wave design approach as it could occupy a larger circuit area and contribute losses. Therefore, the topology implementation of Fig. 1(a) could be more practical at mm-Wave, comparatively.

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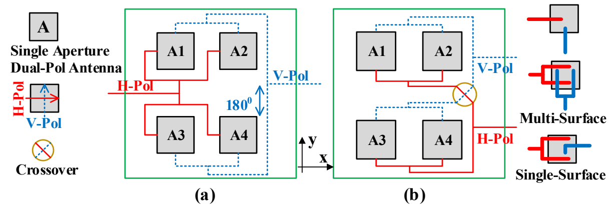

Fig. 1. Single surface microstrip line feed-network topologies; components' definition, and excitation mechanisms' definition

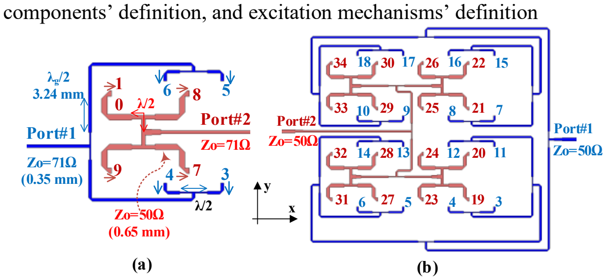

Fig. 2. Packaged MSL feed networks for 2×2 and 4×4 dual-pol arrays

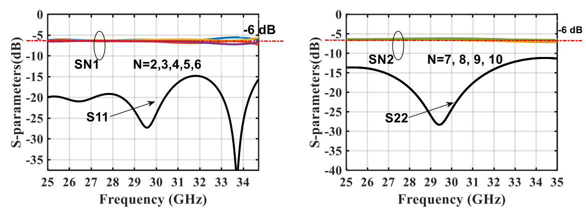

Fig. 3. Reflection and transmission coefficients for 2×2 array feed

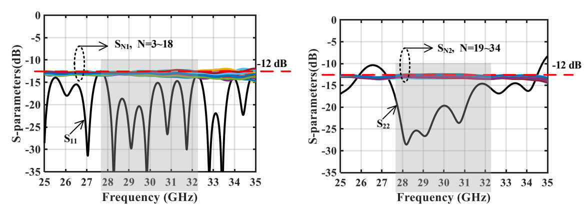

Fig. 4. Reflection and transmission coefficients for 4×4 array feed

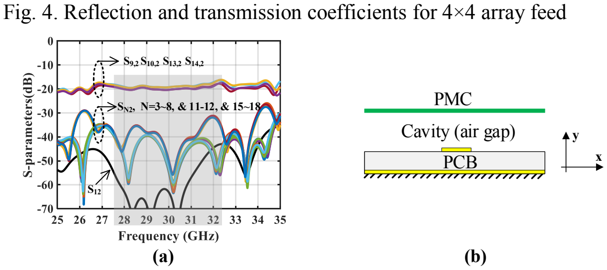

Fig. 5. (a). Coupling coefficients analysis for 4×4 array feed-network, and (b). A PMC packaged microstrip line circuit design environment

In Fig. 2, PMC packaged feed-networks for 2×2, and 4×4 dual-pol arrays are presented. The reflection (S_{NN}) and transmission coefficients (S_{N1}, S_{N2}) for the former and the latter case are plotted in Fig. 3 and 4, respectively. The important performance parameters are the coupling

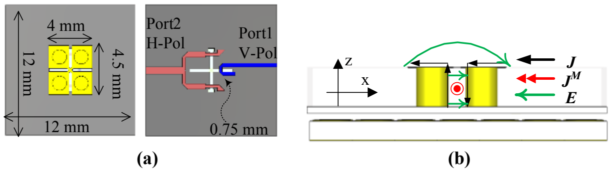

Fig. 6. ME-dipole dual-pol antenna design. (a). Front and back views, and (b) Side-view showing four-layers

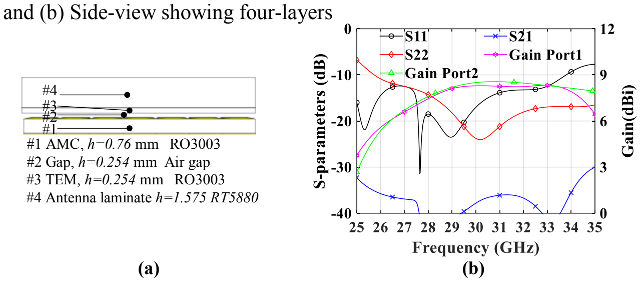

Fig. 7. (a). Antenna layers' description, and (b). S-parameters and gain

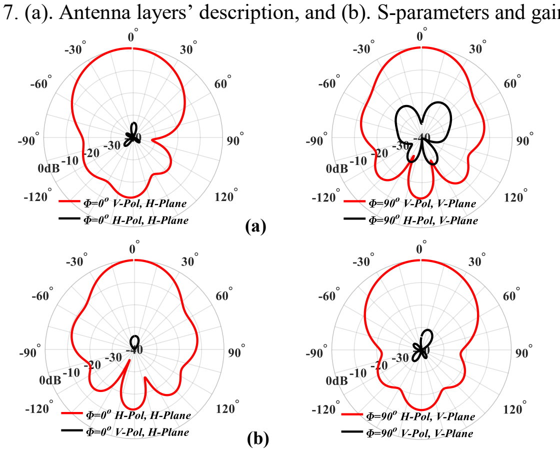

Fig. 8. Element radiation pattern at 30 GHz for (a). V-Pol, (b). H-Pol

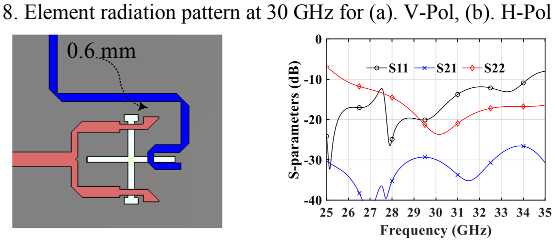

Fig. 9. Feed arrangement within an array environment and S-parameters

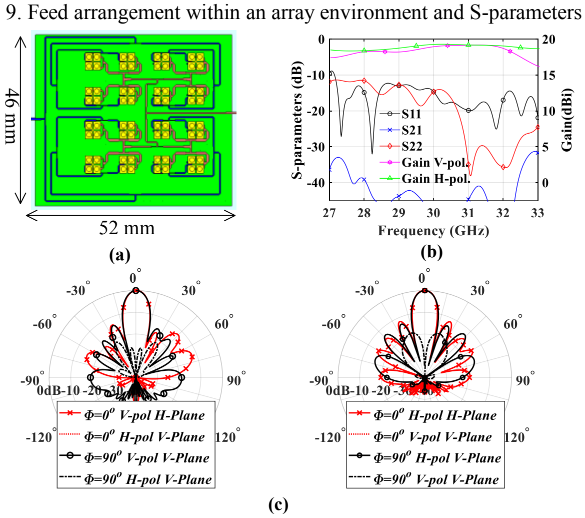

Fig. 10. (a). 4×4 array layout, (b). S-parameters and gain values, and (c). Radiation pattern at 30 GHz

coefficients between the H/V-pols, as shown in Fig 5(a) for a 4×4 network. All ports' coupling coefficients are less than -30 dB, except S_{N2} (N = 9, 10, 13, 14), which is around -20 dB. It is expected that within the array environment, these couplings could contribute to x-pol of the antenna array. Therefore, along with port-to-port coupling, it is very important to analyze the x-pol of the antenna circuit. Another information that needs to be noticed is that the impedance bandwidth decreases with an increase in the array-order. The feed-network is designed within a PMC packaged environment that is also illustrated in Fig. 5(b).

III. Antenna Feed Mechanism and 4×4 Array Design

A dual-pol ME-dipole antenna is shown in Fig. 6. As the array feed network is on a single surface; therefore, hook-shaped and fork-shaped feeds are designs to avoid MSL crossovers/bridges. The performance of a standalone element is given in Fig. 7 and Fig. 8 for S-parameters and H/V-pol radiation. The ports are isolated by more than 30 dB by adjusting the offset parameter d=0.75 mm. The radiation patterns are symmetric within a view-range of 45^0 and x-pol < -30 dB except for V-pol $\varphi=90^{0,}$ where the x-pol level is high, comparatively. Due to offset feed, the antenna exhibits a marginal beam-squint. Therefore, H-pol radiation characteristics are more stable than V-pol across frequency. However, the antenna element has to be used within the array environment where the feedlines are very close to one another. The minimum spacing between the adjacent MSLs of H/V-pol is 0.6 mm, as shown in Fig. 9(a). In this case, the ports' isolation decreases to a level of 27 dB.

The two phenomena, 1. coupling within the feed-network and 2. antenna feed mechanism within an array environment, may result in a high x-pol level. To observe the polarization purity, a 4×4 array is simulated while considering all the material losses, as shown in Fig. 10(a). From the array S-parameters in Fig. 10(b), the ports are isolated by more than 35 dB for 28~32 GHz. The symmetrical radiation patterns are shown in Fig. 10 (c) at 30 GHz have x-pol level up to -20 dB.

IV. Conclusion

A printed array feed network on a single surface along with two different types of feedlines for antenna elements' excitation has been used to analyze the polarization performance of a 4×4 array. This simplified/compact design has provided a port isolation > 30 dB and x-pol < -20 dB.

References

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