Design of Microstrip Antenna Array Feeding Structure with -22dB Side Lobe Level

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Abstract — **Microstrip feeding structure has been modeled, designed and fabricated for 16-element linear antenna array to provide side lobe level (SLL) about 22dB below main lobe level (MLL). The structure has been constructed on the basis of 3dB-hybrid ring coupler as well as various components of Wilkinson-type power dividers with different power split ratios at the output ports.**

Analytical results have been verified experimentally of considered structure fabricated on RT-Duroid substrate material with thickness h=1.27mm and electric permittivity ε_r=10.2 at midband frequency F=1.06GHz.

The achievements of this study demonstrate the accuracy of applied simulation tools as well as the potential utility of analyzed structure as antenna feeder.

Keywords **— Microstrip antenna array, power dividers.**

1. Introduction

In many applications it is necessary to have antenna with with high gain, high radiation efficiency and narrow beamwidth to meet demands of both long distance communication and millimeter-wave applications.

Although single antenna element doesn't usually provide the requirements needed, noticeable improvement can be achieved by using an array, [3].

Array feeding structure is an important factor, which must be considered carefully or it may affects the system as a whole [8],[9].

Moreover, the side lobe levels (SLL) and half-power beamwidth (HPBW) are usually the most important characteristics in the array distribution, which must be optimized to a specific value depending on the required application. While the uniform distribution can be realized easily by means of 3dB power dividers [10], it is characterized by its high SLL. The alternative solution for obtaining low SLL can be achieved by the application of nonuniform (tapered) amplitude distributions [5].

The purpose of this paper therefore is to design the feeding structure needed to provide the suitable power ratios satisfying the required excitation coefficients of chosen distribution. Usually the dynamic amplitude ratios of excitation coefficients of array elements i.e.the ratio of maximum excitation coefficient to minimum one ($A_{max}\backslash A_{min}$), dictates the shape of the feeding structure.

2. Design Of the Feeding Structure

To deal with microwave integrated circuits (MIC) fabricated on inhomogeneous, stratified substrates, accurate, as well as fast and efficient simulation tools are needed.

In this simulation procedure, LINPLAN [2] was used to obtain the ideal excitation coefficients (IEC) for the Chebyshev tapered distribution to build a feed structure with ideal side lobe level about 22 dB below MLL.

To realize the (IEC) for this structure, both 3dB hybrid-ring coupler as well as various versions of Wilkinson-type power divider were analyzed and designed with a specific power division ratios [1], [6], [7],[10].

Standard commercially available simulation package provided by Libra [4] was used to simulate and design the entire microstrip feed structure, which was fabricated on one layer substrate.

Fig.1 represents the general block diagram of the feeding system in which it is symmetrically excited around the central elements (patches $A_{N/2}$ and $A_{N/2+1}$).

Let us consider any N-element of linear microstrip antenna array with nonuniform (tapered) amplitude distribution, as shown in Fig.1. To design a feeding system the excitation coefficients dependent on the desired side lobe levels (SLL) and half power beam width (HPBW), should be determined. Such coefficients will be called as ideal excitation coefficients (IEC), and they can be easily calculated for different tapered distributions (e.g. Chebyshev, Taylor, cosine,..etc.) [2].

Simulated excitation coefficients (SEC) have been obtained by Libra^{TM} of HP Eesof [4]. They are generally different from IEC, and hence, at this stage of the design we should verify whether they could be accepted from the point of view of the deterioration of the required SLL and HPBW. Thus, it is clear that IEC cannot be met in practice. Next, during the fabrication and measurement of the feeding structure we obtain so called measured

excitation coefficients (MEC), which of course differ from SEC since even most sophisticated numerical tools do not accurately take into account all physical phenomena affecting the parameters of structure under analysis.
It is worthwhile to mention that the proposed classification of excitation coefficients is chosen to utilize all advantages of available software program packages, providing broader basis of discussions concerning design procedure of the feeding structure.

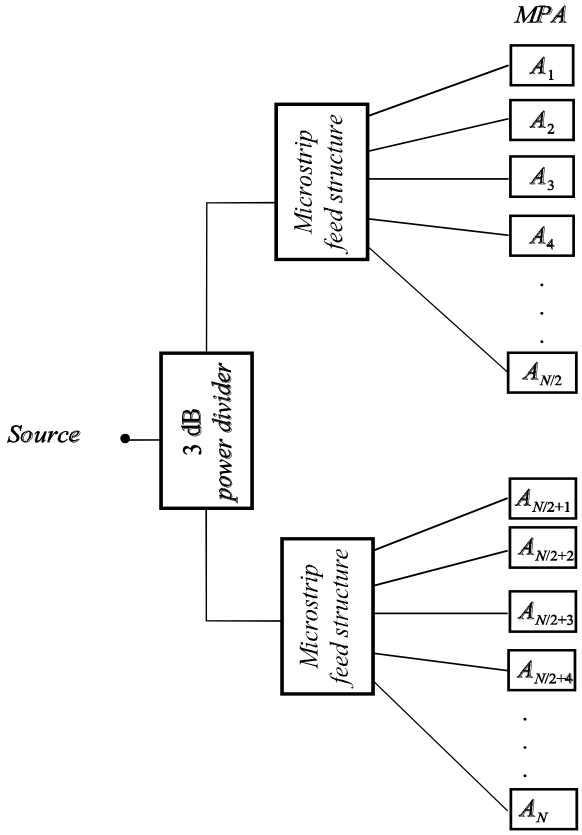

Fig.1 General block diagram of linear microstrip antenna feeding structure

Table.1
IEC, SEC and MEC power distribution and differential phase shifts for MPA elements with feeding structure

	MPA	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
S[-dB]	IEC	19	16.7	14.4	12.7	11.4	10.5	9.9	9.6
θ [Deg]		0°	0°	0°	0°	0°	0°	0°	0°
S[-dB]	SEC	19.4	17.1	14.8	13.2	12	11	10.5	10.2
θ [Deg]		-103	-72.5	-1.7	6.1	44.6	43.6	-41.7	-64.5
S[-dB]	MEC	18.9	16.7	14.7	13	12	11.1	10.7	10.3
θ [Deg]		-70	-58	152	138	-174	137	52.5	38.6

All simulations were performed, for Chebyshev feed structure of linear antenna array with 16 elements, printed on RT Duroid material of thickness h = 1.27mm and relative electrical permittivity $\varepsilon_r = 10.2$. The simulations were performed for the midband frequency F = 1.06 GHz. It is worthwhile to mention, due to the sake of simulation, ideal microstrip patch antenna elements (MPA), were considered in this paper which, spaced by $\lambda_0/2$, where λ_0 is the free space wavelength.

The proposed Chebyshev feeding structure must provide ($A_{max}\backslash A_{min} \cong 9.5$dB) to achieve SLL about 22dB below MLL.

3. Numerical and Experimental Results

Tables 1-3 demonstrate results concerning Chebyshev feeding structure constructed on the basis of 3dB hybrid-ring coupler as well as various components of Wilkinson-type power dividers with different power split ratios at the output ports. Excellent convergence is observed between theoretically simulated results and experimentally measured data as shown in related tables.
Table-1 represents the ideal (IEC), simulated (SEC) and measured (MEC) power distributions for Chebyshev feeding structure with the corresponding differential phase shift (θ) at every radiating element at the central frequency F=1.06GHz.
This excellent convergence between simulated results and measured data confirms the accuracy of the design procedure for the discussed feeding structure. On the other hand, if we compare both simulated and measured amplitude distributions with the ideal ones, the differences are more considerable as demonstrated by Table-1. Whereas, errors are located between 5 to 7% for simulated amplitudes, the measured ones are limited between 2 to 9%, for loosely and strongly coupled outputs, respectively. These differences, which are still in the acceptable range may be due to either design, fabrication or measurement tolerances.
Table-2 represents the absolute amplitudes of different elements (A_N) normalized to that of maximum element (A_{max}) for IEC, SEC and MEC as referred to data in Table-1 for Chebyshev feeding structure with SLL =22.2dB below MLL at design frequency.

Table 2
IEC, SEC, and MEC for the structure with 22.2dB SLL at design frequency F=1.06GHz

EC	Antenna element							
	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
IEC	0.3372	0.443	0.576	0.702	0.813	0.9	0.967	1.0
SEC	0.3435	0.45	0.585	0.71	0.813	0.91	0.96	1.0
MEC	0.374	0.48	0.606	0.736	0.825	0.922	0.96	1.0

The discussed feeding structure is designed for central frequency, at which we consider equal phase shifts for all radiating elements. Although, the results shown in Table-1 demonstrate different phase shifts at the outputs, the equalization of these phases is usually possible for any single frequency by means of inserting additional phase shifting elements to the structure. In this work we optimize the lengths of all branches of the structure to obtain 0° at all different radiating elements for the design frequency F=1.06GHz with all different kinds of excitation coefficients (EC).
As can be seen from Table-3, SLL fall due to the change of the amplitude of excitation coefficients is small (~1dB). In addition, the achieving of narrow HPBW for the feeding structure discussed here, is visible for all different kinds of

excitation coefficients, with no change occurred in HPBW for all different classifications.

Table-3

SLL and HPBW for IEC, SEC and MEC of the structure

Coefficients	IEC	SEC	MEC
SLL [dB]	-22.27	-21.95	-21.01
HPBW	7.5°	7.5°	7.5°

Although, SEC and MEC are significantly deviated from IEC, especially for strongly coupled outputs (Table-2), very good convergence between ideal, simulated and measured array factors is visible. The corresponding deviations from the ideal case in side lobe levels for SEC and MEC are 0.32dB and 1.26dB, respectively. This confirms that side lobe levels of the discussed structure are not very sensitive to the change of excitation coefficients. Moreover, the half power beam widths are kept unchangeable for all different classifications.

4. Conclusions

Chebyshev- tapered distribution, feed structure has been modeled, designed and fabricated for 16 element linear array of microstrip antenna to provide SLL about 22dB. The results of the modeling of electrical behavior of the structure, fabricated in integrated microstrip line based technology have been presented and concluded. Analytical results have been verified experimentally of considered feeding structure fabricated on RT-Duroid substrate material with thickness h=1.27mm and electric permittivity ε_r=10.2 at mid-band frequency F=1.06GHz. The experimentally measured results of the proposed structure exhibit a full agreement with theoretically simulated data. The proposed structure has shown reliable results as it has smaller dynamic amplitude ratio of EC, which is very important for technological reasons and narrower beamwidth required for certain applications. The reported results show a small deviation in SLL and no change in HPBW for discussed structure which is due to the excellent convergence for both simulated and measured data concerning magnitude and phase shift difference for radiating elements.

The performed results obtained from this study demonstrate the accuracy of applied simulation tools as well as the potential utility of analyzed structure as antenna feeder. Finally, in author's belief, the results obtained during the course of this study are considered to be very important for designers of 1-D and 2-D array feeding systems.

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