A Fully Integrated Scanning Receiver Array

Wolfgang Menzel, Ziqiang Tong

Microwave Techniques, University of Ulm, PO Box, D-89069 Ulm, Germany
Tel.: +49-731-5026350, Fax: +49-731-5026359, E-mail: wolfgang.menzel@ieee.org

Abstract — **In this contribution, an integrated antenna-receiver array is presented. The RF signal is received by open waveguide ports connected to finline mixers. A chain of suspended stripline bandpass filters is used as LO feed network where phase shifting occurs as a function of frequency. Combining the IF signal in a fixed equal-phase network, the antenna array characteristic is scanned varying the LO frequency from -35° to +35° while the RF frequency is kept constant. The overall very compact arrangement is integrated on a single substrate and placed in a compact metal mount.**

Index Terms — **Antenna array, frequency scanning array, receiver array, microwave integrated circuits, planar filters, finline mixers.**

I. Introduction

Antennas with electronic scanning facilities are becoming increasingly important. Often this is associated with increasing loss and cost using conventional phased array techniques. A possible solution is the use of frequency scanned arrays, as it is demonstrated for automotive radar applications, e.g. in [1]. A frequency sweep, on the other hand, poses other problems, e.g. it reduces range resolution for a FM/CW radar sensor. In [2-4] alternative approaches have been presented using heterodyne principles with a frequency variation in the LO path. Thus, RF frequency can be kept constant, and available bandwidth can be fully exploited for other purposes. In order to keep the LO and, consequently, the IF frequency variation small, long delay lines between the tapping points of the LO feed line have to be selected, leading to increased losses, especially for increasing frequencies. Recently, it has been shown that, based on an original concept of composite right/left handed transmission line [5], very compact, low-loss suspended stripline bandpass filters can be employed as strongly frequency dependent phase shifting devices, and a scanning range of more than ±45° over a relative bandwidth of 12% has been demonstrated. Such a compact and planar approach now enables an easy integration with planar mixers.

In this paper, a six-element receiver array is described incorporating suspended stripline bandpass filters and finline mixers.

II. Setup of the Receiver Array

A basic block diagram of the scanning array is given in Fig. 1. The LO signal is distributed via a chain of suspended stripline bandpass filters with the passband frequency range from 8.5 GHz to 9.5 GHz. (The RF frequency of the receiver array is 10.5 GHz, resulting in an IF frequency range of 1 GHz to 2 GHz) . The structure of the filters is shown in Fig. 2. Quasi-lumped, capacitively coupled resonators are used with inductive shunt elements [6]. With such filters, length can be kept small – a four resonator filter as used within this work has a length of only half a free-space wavelength. Insertion loss is a few tenths of a dB only. The order of the filters was selected to four, resulting in zero phase angle and therefore broadside radiation of the antenna array at the center frequency (Fig. 3).

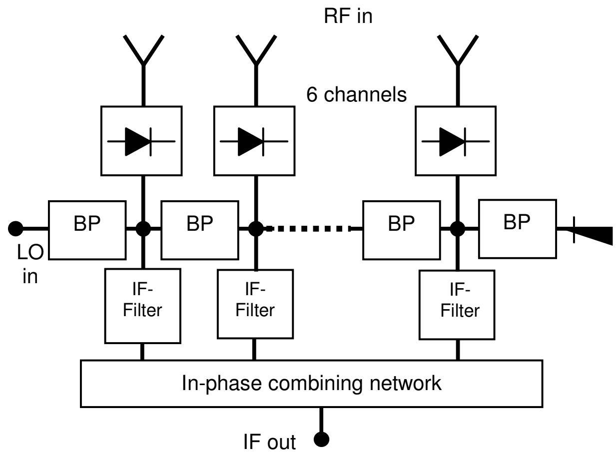

Fig. 1: Basic block diagram of the scanning array.

Between the bandpass filters, taps are introduced to guide part of the LO power to each of the six mixers using a matching structures for the LO impedance of the mixer. As the IF frequency is relatively low, microstrip IF filters could be arranged on the opposite side of the filter chain (Fig. 1 and 5). The principle structure of a finline mixer [7] is given in Fig. 4; the combination of finline slot and coplanar line forms a 180° hybrid junction for the balanced mixer function. A taper in the RF path forms a transition to standard waveguide; open waveguides are used here as radiating elements.

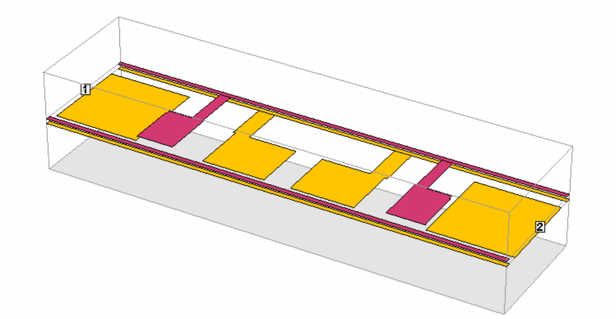

Fig. 2: Basic structure of the suspended stripline bandpass filter. Orange/light color: lower metallization layer, red/dark color: top metallization layer.

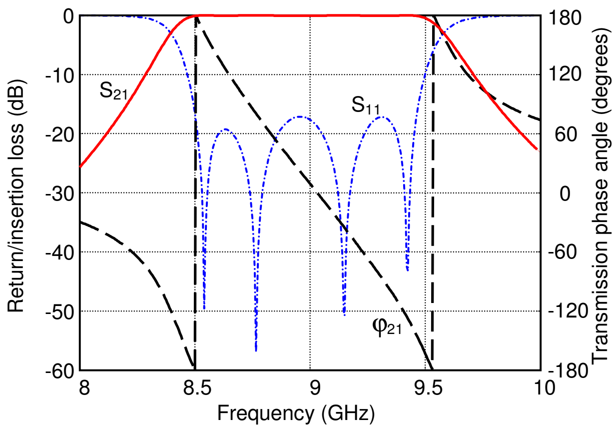

Fig. 3: Simulated return and insertion loss as well as transmission phase angle φ_{21} of the suspended stripline bandpass filter.

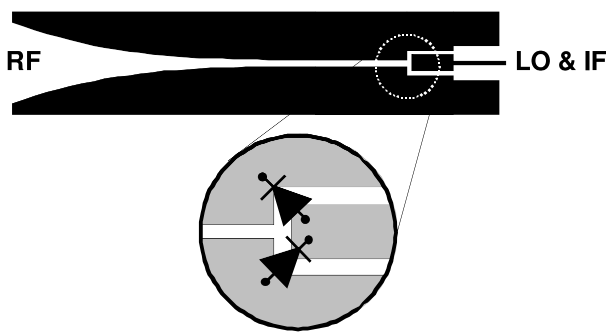

Fig. 4: Principle structure of the balanced finline mixer.

The complete receiver array is fabricated on RO 4003 substrate material. This material can easily be processed using standard printed circuit board techniques including vias. Thus, the overall arrangement is placed on a single rectangular substrate (Fig. 5). The substrate then is placed between the two parts of an aluminum mount. Bottom and top parts of the mount include the necessary channels for the suspended stripline as well as the RF waveguide portion, while rows of vias in the substrate along the channels provide the contact through the substrate.

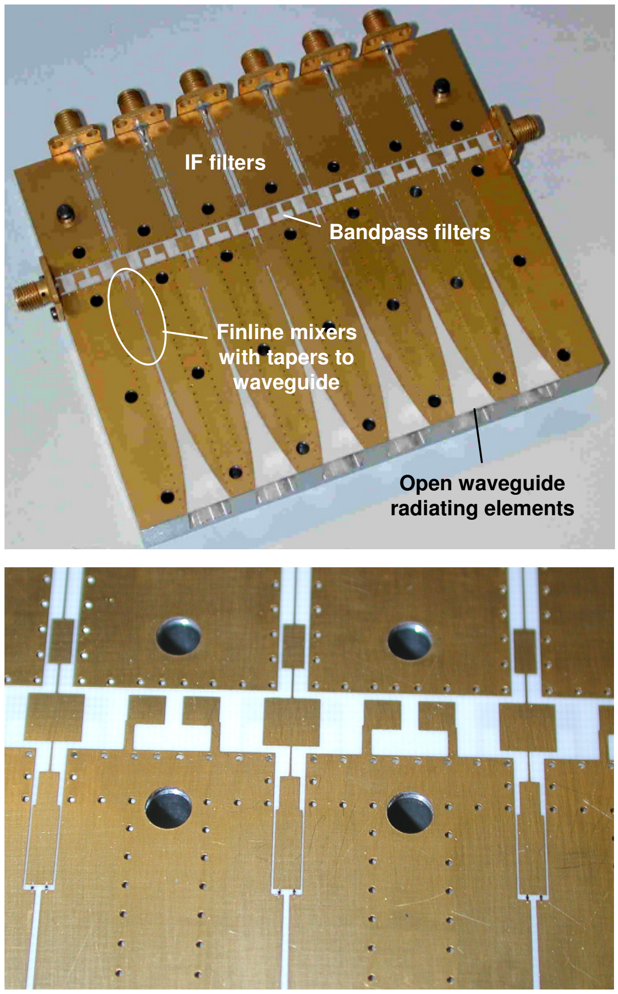

Fig. 5: Photograph of the opened antenna array block (top) and detailed view on part of the arrangement (bottom).

III. RESULTS

The assembled receiver array is shown in Fig. 6, together with an external power combiner for the IF signals. An amplifier was used to provide sufficient LO power for the six mixers.

The LO power is fed into one side of the arrangement, while the other side is terminated by a matched load. LO return loss is plotted in Fig. 7; due to the comparably long and complex structure, a strong ripple can be seen. The lower edge of the filter passband, as indicated by this curve, is slightly lowered to 8.2 GHz. In contrast to a first design, the return loss has a reasonably good value also for the center frequency of the filters where all contributions to the reflection add up coherently – this is a problem often encountered with frequency scanned antennas going through the broadside radiation regime.

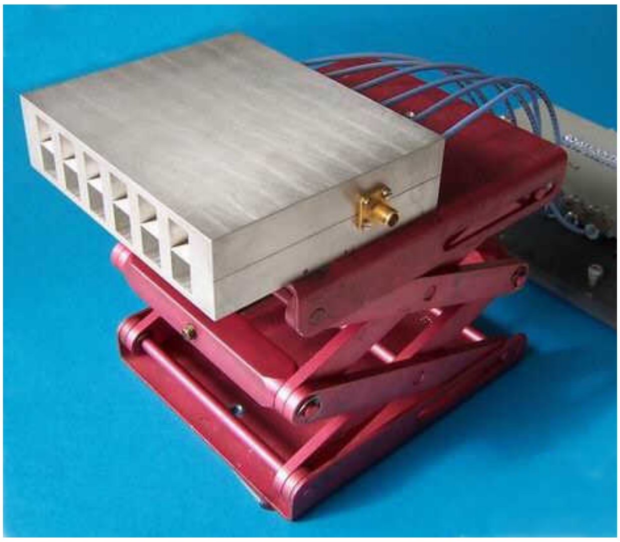

Fig. 6: Complete receiver array.

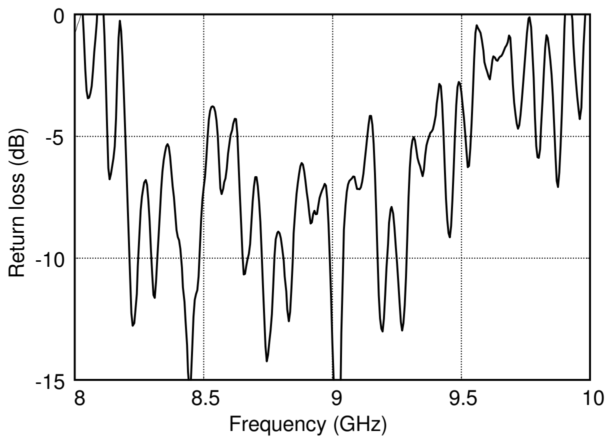

Fig. 7: LO return loss of the antenna arrangement.

A special arrangement had to be used to measure the radiation diagrams, as input and output frequency are different [8]. To this end, another single mixer was used to downconvert a small portion of the transmit signal with the same LO source as for the antenna serving as reference signal for the network analyzer. The received (and downconverted) signal then was fed to the second input of the analyzer which was operated in a dual frequency mode (Fig. 8). Fig. 9 shows the E-plane radiation diagrams for seven different frequencies. A beam scanning from about -35° to +35° is demonstrated with a LO frequency variation of 0.7 GHz (Fig. 10). An even wider scanning range is possible with wider beamwidths and some deterioration of the antenna diagram. As no measure was undertaken to provide an amplitude taper (which easily could be done in the IF combining circuit), sidelobe level is in the range of 10 dB to 14 dB.

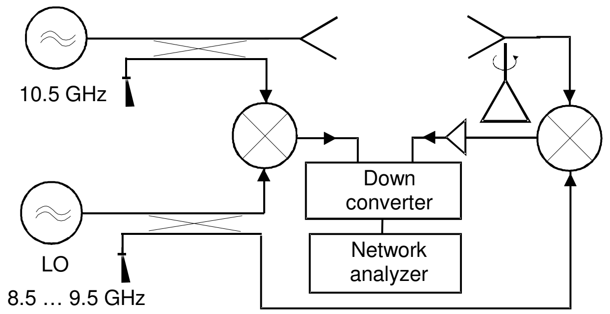

Fig. 8: Setup for the antenna measurement.

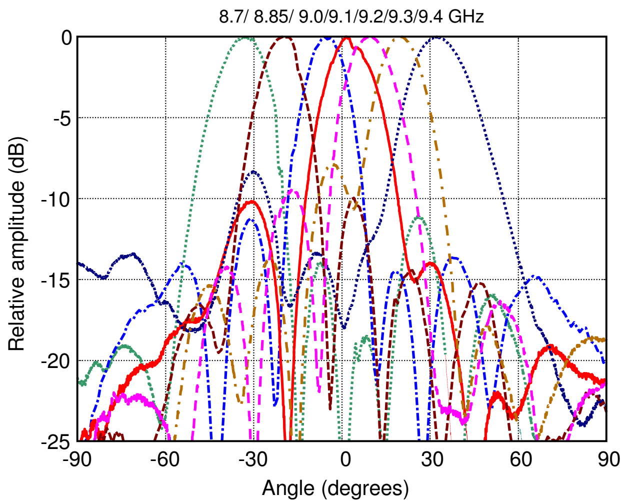

Fig. 9: E-plane radiation diagrams for seven different LO frequencies (f_{RF} = 10.5 GHz).

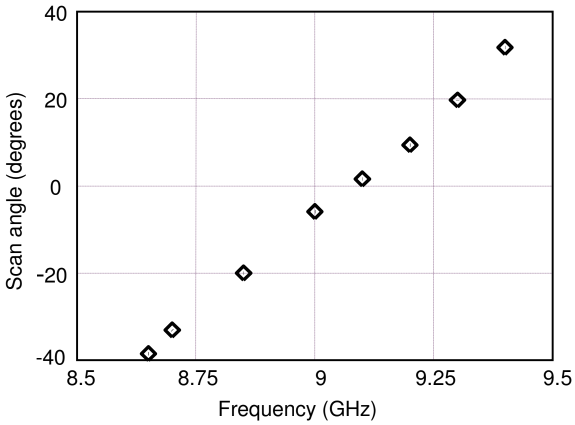

Fig. 10: Measured scan angle as a function of LO frequency.

IV. CONCLUSION

Based on an earlier work to employ suspended stripline bandpass filters as phase shifting elements for a frequency scanned antenna, this approach has been extended by finline mixers to realize a scannable receiving antenna array with constant RF frequency. Scanning is performed modifying the LO frequency. A scanning range of about ±35° has been demonstrated experimentally with a LO variation from 8.7 GHz to 9.4 GHz. As has been shown earlier in [4], such an arrangement can equally be operated in an upconverting mode, thus in principle, both receive and transmit functions can be performed with such an array.

REFERENCES

[1] Relph, P.M., Griffiths, H. D.: An electronically scanning antenna for automotive radar systems. IEEE Colloquium on Automotive Radar and Navigation Techniques, 1998, pp. 535-537.
[2] Nishimura, T., Ishii, N., Itho, K.: Beam scan using the quasi-optical antenna mixer array. IEEE Transactions on Antennas and Propagation, July 1999, pp. 1160-1165.
[3] Kim, M., Hacker, J.B., Sailer, A.L., Hong, J.H.: A heterodyne-scan phased-array antenna. IEEE Microwave and Guided Wave Letters, 1999, pp. 535 - 537.
[4] Schmid, U., Menzel, W.: A 24 GHz Scanning Receiver Array. ANTEM 2002, Montreal, July 30 - August 02, 2002, pp. 319 - 322.
[5] Menzel, W., Sathiaseelan, M.: Frequency Scanned Antenna Array Using a Suspended Stripline Negative Index Transmission Line. Europ. Microw. Conf. 2005, Paris, Oct. 2005, pp. 253 -256.
[6] Menzel, W., Balalem, A.: Quasi-Lumped Suspended Stripline Filters and Diplexers. IEEE Trans. on MTT, vol. MTT-53, Oct. 2005, pp. 3230 - 3237.
[7] Menzel, W.: Finline components. Wiley Encyclopedia of Electrical and Electronics Engineering, Vol. 7, John Wiley & Sons, New York, pp. 538 – 544.
[8] Menzel, W., Werner, R.: A high dynamic range extension for antenna measurements in the mm-wave range. MIOP 2001, Stuttgart, Germany, pp. 194 - 197.