Deliverable 3.7: Edited Evaluation Report Integrated Package #2

Millimeter-wave technology paves the way to next generation wireless applications, e.g. high-bandwidth LAN at 60 GHz, E-band vehicular collision avoidance at 77 GHz and 94 GHz imaging radar for security and defense are some prominent examples. Volume manufacture requires either system-on-chip (SoC) or system-in-package (SiP) realization. The SoC solution integrates passive and active components on a wafer but yield suffers and real estate is increased, whereas SiP allows embedding active components into low-loss substrates. The latter approach presents an opportunity to mix active components manufactured with different processes, to reduce losses in passive components such as inductors and allow real estate intensive antennas to be patterned. There is a growing demand for using inexpensive printed circuit board substrates (PCBs) in SiP designs. To address these requirements here we are developing softboard technology for mm-wave applications. In particular, and in association with substrate manufacturers as well as advanced PCB developers we have measured the electromagnetic performance of a new softboard PTFE based substrate and demonstrated its use in delivering high performance filters and antennas. Details relating to these activities are reported in references [1-3].

**Mm-wave characterisation**

Knowledge of the electromagnetic PCB substrate parameters is vital for accurate design, especially in the mm-wave range where dimensions based on electrical characteristic such as substrate permittivity are tolerance critical. Today most substrate PCB manufacturers specify the dielectric parameters of their substrate materials at 10 GHz. Consequently in realized designs at mm-wavelengths frequency shifts attributed to permittivity deviation commonly occur.

Mm-wave dielectric characterization of printed circuit board materials using a new substrate integrated waveguide resonator technique has been undertaken [1]. A launching mechanism using GSG probing of a u-shaped slot has been proposed to facilitate measurement and accurate de-embedding at millimeter-wave frequencies. Special attention has been paid to the accurate extraction of the unloaded resonant frequency for single-port resonators. A comprehensive set of test samples was designed and measured over the 60 to 110 GHz frequency range, Figure 1. The retrieved substrate permittivity is in good agreement with the known nominal value specified by manufacturers at 50GHz. The method is also robust with respect to the aperture dimension deviations, making the method less sensitive to etching tolerances hence more readily extendable to deployment at higher frequencies. It has been shown that the metal roughness effect is crucial for the estimation of the loss tangent. Thus for the smooth metallization assumption the loss tangent extracted is by 34-40% larger than the specified, i.e. 0.0011 c.f. 0.0008. However, once the surface roughness is properly taken into account the mean value loss tangent has become about 0.0007 or only 8-14% lower than specified. Based on these results and the fact that the same geometrical configuration of a cavity can be used for characterization of different substrate thicknesses this method is suitable for mm-wave testing of printed circuit board substrates as an alternative to the more restrictive microstrip and stripline resonator methods.
SIW Antennas

A novel W-band hybrid wide-angle frequency-scanning SIW leaky-wave antenna architecture has been developed [2], Figure 2. Three antenna prototypes suitable for this architecture have been designed in SIW technology. The ensemble of the three antennas covers elevation angles from 13° to 55° by frequency scanning within a 6.5% bandwidth with an approximately constant 10° beamwidth. Prototypes have been fabricated and tested. Good agreement between the simulated and experimental results has been obtained. Coverage of elevation angles between 11° -56° has been demonstrated, with radiation efficiency over 89% in the entire scanning region. The compatibility with PCB technology and wide elevation scanning capability within a narrow frequency band make the proposed W-band antennas an attractive solution for intelligent mobile sensing and communications applications.

SIW Filters

Two novel V-band filters with quasi-elliptic responses have been developed [3], Figure 3. Design procedures for the filters synthesis, physical mechanisms providing quasielliptic response and de-embedding of the measured results have been explained. The insertion loss of the filters is measured below 2 dB when microstrip-to-SIW transitions are included. The return loss in passband is measured below 10 dB, which is to be improved in future work. The filters have sharp roll-off due to the transmission zeros and the out-of-band rejection in the upper stopband of 10 and 17 dB. Both filters can be used as an advanced packaging solution for V-band wireless personal network front-end applications.
Fig. 3: Fabricated SIW V-band pseudoelliptic bandpass filters with measured and simulated responses

References