As we are interested in testing wireless communication systems, a way to verify the proposed set-up is to transmit a signal from several transmitters, acquire it, and then estimate (1) the beginning of the received block as well as (2) the channel. When repeating the transmission, these two estimates should not change significantly in a static environment.

C. Repeatability

If repeating an experiment requires a transmission to happen at a specific time the proposed set-up may not be sufficient. The reason is that firstly, in Step (c) in Figure 4, a packet has to be sent to the sync-unit resulting in an unknown delay next to the fixed time t_{L} that cannot be avoided. Secondly, it is very hard to time UDP datagrams in software more accurately than in a microseconds [10]. We therefore implemented an external hardware input into the sync-unit.

D. Achievable Triggering Speed

When transmitting blocks of data, the latency introduced by the triggering is the sum of:

1) the time required to tell the sync-unit to trigger (Step (c) in Figure 4), that is, the delay of a network switch,
2) the time required by the sync-unit to receive and transmit UDP packets as well as to read the internal clock (the vertical lines of Steps (d) and (e) in Figure 4), that can be made negligible by employing high-speed hardware, and
3) the estimated maximum time required to broadcast the trigger time over the network (Step (d) in Figure 4).

*) Note that the time required to receive the success report (step (e) in Figure 4) is not included in the sum, as the received data can already be evaluated (Step (f) in Figure 4) while waiting for the success report.

Therefore, if only triggering, triggering speeds of more than one trigger per millisecond can be easily achieved in typical LANs.

However, in a real measurement, the transmission not only has to be triggered but data also has to be generated, transmitted, and received. If employing off-line processing of data, the triggering itself will only account for a negligible part of the overall measurement time (far less than 10%). It is therefore not necessary to optimize the speed of the triggering procedure anymore.

IV. Our Hardware Implementation of the Sync-Unit

The synchronization unit has been implemented in hardware (see Figure 7) and tested in various local area network environments. For example, if "generating the TX samples and loading them into the FIFOs" (step b in Figure 4) takes 4 ms and the data is transmitted while the next block is already loaded, a rate of 233 transmitted data blocks per second has been reached in a local area network. A detailed analysis can be found in [11].

V. Conclusions

In this paper we presented a method to synchronously trigger hardware at different locations using a GPS and a dedicated sync-unit at each site, as well as an already existing LAN infrastructure. We showed that the precision of the overall set-up can be further increased by employing rubidium frequency standards and external local oscillators.

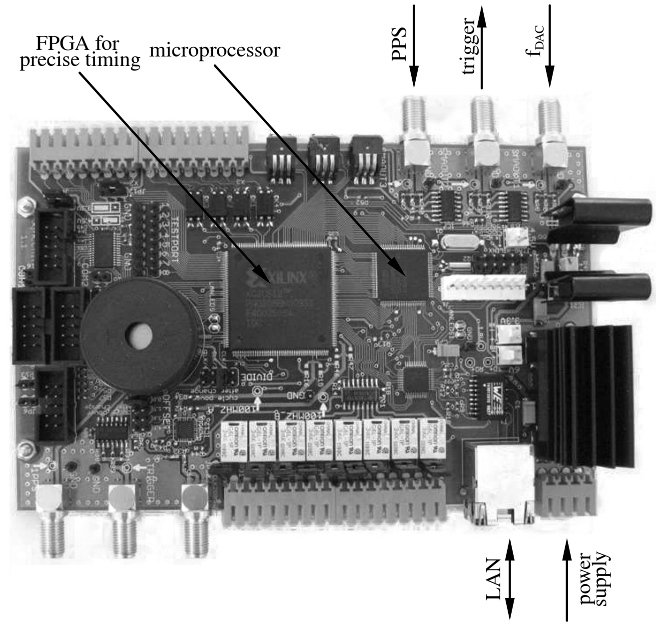

Fig. 7. Sync-unit built. The unit incorporates a host of additional input/output connections in order to control other hardware such as step attenuators, linear guides, rotation units, and radio frequency switches.

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