R&S® FSW signal and spectrum analyzer: measuring E band microwave connections

The growing volume of data traffic due to the use of wireless devices calls for high bandwidths for connecting base stations to the network. Two 5 GHz frequency bands between 71 GHz and 86 GHz are available in the E band for point-to-point connections. The high frequencies are a challenge for T&M equipment; not only when developing transmit and receive modules, but also when measuring transmission systems.

E band: extra bandwidth for more data

Over 30 years ago at the World Radiocommunication Conference WARC-79 in Geneva [1], the International Telecommunication Union (ITU) passed the decision to dedicate the E band frequencies from 71 GHz to 76 GHz and from 81 GHz to 86 GHz for transmission applications. It took more than 20 years before commercial interest in these applications emerged and led the US Federal Communications Commission (FCC) and European authorities to issue licenses for these bands and to specify the technical requirements for their use. The reason why interest finally evolved was that, by now, it had become possible to commercially manufacture components for this frequency range. At the same time the demand for increasing transmission rates made it necessary to use new frequency bands. Transmission links with data rates of several Gbit/s are no problem in the E band. The two frequency bands, each with a continuous range of 5 GHz, make transmission bandwidths of several 100 MHz possible. Combined with a simple modulation method such as BPSK, high data rates can be achieved. Consequently, it is possible to implement simple and reliable transmit and receive modules for these millimeter-wave connections. It goes without saying that more complex types of modulation may be used as this technology evolves. The achievable range in these frequency bands is only insignificantly shorter than for example in the 38 GHz band. This was proven with open field tests done in normal weather conditions with an attenuation of 0.5 dB/km [2].

The high frequencies pose new T&M challenges. Although licensing protects against interference from other microwave sources, the power and spectrum of the transmitters must be measured to ensure disturbance-free coexistence of licensed communications. The requirements for transmitters in this frequency range, especially for the radiated power (EIRP) spectrum density mask, are described in [3].

Spectrum measurements in the E band – harmonic mixers are essential

Spectrum analyzers are the most suitable instruments for these sophisticated measurements. However, commercially available spectrum analyzers have a continuous frequency range of up to 67 GHz only. To carry out spectrum measurements in the E band, they must be used together with external harmonic mixers [4]. The mixers multiply the spectrum analyzer’s local oscillator output signal and use a suitable harmonic to downconvert the millimeter-wave signal to be measured to the analyzer’s intermediate frequency. However, the large number of harmonics created in the mixer and the input signal’s harmonics produce a multitude of signals in the spectrum. The image frequency is not suppressed because there is no preselection.

This will not create any problems as long as only CW signals are present at the mixer’s input. With this type of signal, the spectrum analyzer can tell the difference between real signals and unwanted mixing products and their image-frequency signals that are present at the mixer output. To enable this distinction, the analyzer conducts a reference measurement prior to the actual measurement. During the reference measurement, the local oscillator frequency is increased to a value that is twice the intermediate frequency. Only signals that are detected in the reference measurement and in the actual measurement are real signals and are displayed in the spectrum.

Additional articles about the R&S® FSW signal and spectrum analyzer in this issue:
The new R&S®FSW43 and R&S®FSW50 models are introduced on page 38. Read how a new option enables precise, quick and wideband measurement of group delay on page 43.
If modulated signals are present at the mixer input, the task is more complicated. The real signal and the signal received on the analyzer’s image frequency may overlap each other, especially in the case of very wideband signals, so that it is no longer possible to tell them apart.

**Spectrum measurement**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>RBW</td>
<td>2 MHz</td>
</tr>
<tr>
<td>VBW</td>
<td>10 kHz</td>
</tr>
<tr>
<td>SWT</td>
<td>125 ms</td>
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</tr>
<tr>
<td>Center</td>
<td>72 GHz</td>
</tr>
<tr>
<td>Span</td>
<td>2.5 GHz</td>
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Fig. 1 shows a spectrum measurement performed with the R&S®FSQ, a high-end signal and spectrum analyzer. This instrument no longer belongs to the newest generation and has an intermediate frequency of 404 MHz. The frequency difference between the input signal and the image-frequency signal is 808 MHz. With this 500 MHz bandwidth input signal, it is just still possible to test if it complies with the EIRP spectrum density mask according to [3], by subtracting the reference measurement spectrum from that of the actual measurement. If the input signal had a bandwidth of 1 GHz, that would no longer be possible because the input signal and image-frequency signal would superimpose on each other. The influence of the image-frequency signal would strongly distort time domain analysis of the signal (I/Q data), where correction using a reference measurement is not possible.

**R&S®FSW:**

able to handle wideband-modulated signals

The R&S®FSW [5] signal and spectrum analyzers with the R&S®FSW-B21 option (LO/IF connectors for external mixers) have a major advantage compared to conventional instruments. With an intermediate frequency of 1.3 GHz, the R&S®FSW analyzers have an image-free frequency range of 2.6 GHz. This makes it easy to measure the EIRP spectrum density mask of wideband-modulated signals, even if their bandwidth reaches into the GHz range. Together with the latest generation of Rohde & Schwarz harmonic mixers, e.g. the R&S®FS-Z90 (60 GHz to 90 GHz), the achievable dynamic range is truly unique. The mixer has a typical conversion loss of 23 dB at 80 GHz, resulting in a displayed average noise level (DANL) of approximately –150 dBm/Hz for the complete test setup, including the R&S®FSW. A 1 dB compression point...
of nominally –3 dBm results in a dynamic range sufficient for measuring the spectrum mask. The ETSI technical specification [3] defines a value of 50 dB. The R&S®FS-Z90 harmonic mixer is also equipped with an isolator at the input, which makes a VSWR of typically 1.4:1 possible. Power measurement errors due to reflections at the input resulting from mismatch are typically reduced by a factor of 5 compared to mixers without isolators.

Fig. 2 shows the measurement of the same signal of an E band microwave connection as Fig. 1. The 500 MHz bandwidth input signal and the image signal are 2.6 GHz apart, and it is possible to measure if the spectrum is within the prescribed mask (red line). The required dynamic range of at least 50 dB is also easily achieved with this setup.

The R&S®FSW can measure the spectrum as well as the modulation quality. Its high analysis bandwidth of up to 320 MHz (R&S®FSW-B320 option) makes it possible to capture wideband signals, demodulate them with the R&S®FSW-K70 vector signal analysis option and to analyze the modulation quality.

Fig. 3 shows the analysis of a 300 MHz bandwidth QPSK signal. The error vector magnitude (EVM) as a measure of the modulation quality, as well as the frequency error, the symbol rate error and many more parameters can be measured. The R&S®FSW signal and spectrum analyzer displays the results in tables or graphs. For example, the phase and amplitude are displayed in a constellation diagram, which delivers a visual impression of the modulation quality.

**Summary**

E band microwave connections are becoming more and more popular due to the constantly growing demand for higher data volumes to be transmitted. This range offers the highest achievable data rates of all available wireless transmission technologies. A spectrum analyzer with an external harmonic mixer is required to measure the spectrum. The R&S®FSW signal and spectrum analyzer’s high intermediate frequency offers a wide image-free range. The low conversion loss of the Rohde&Schwarz harmonic mixers provides a high dynamic range, and the good matching results in high power measurement accuracy. This makes the R&S®FSW together with the R&S®FS-Z90 harmonic mixer a peerless solution for spectrum measurements in the E band.

Dr. Wolfgang Wendler

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**References**


[3] ETSI TS 102 524 V1.1. Technical Specification: Fixed radio systems; point-to-point equipment; radio equipment and antennas for use in point-to-point millimeter-wave applications in the fixed services (mmw FS) frequency bands 71 GHz to 76 GHz and 81 GHz to 86 GHz.
