Application Note

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How antenna coupling loss and VSWR affect measurement accuracy

boosting wireless efficiency

Antenna couplers and VSWR

This paper addresses coupling loss and its relevance to RF measurements, their repeatability and accuracy. It also attempts to provide an understanding what the good VSWR (Voltage Standing Wave Ratio) of Willtek's 4916 Antenna Coupler means for the performance of the antenna coupler.

The paper highlights the most significant issues around coupling loss and explains why the attenuation values are slightly higher on the 4916 compared to other couplers, and why this does not matter!

Principle of the antenna coupler

A couple of years ago mobile phones had proper antenna connectors, which allowed for conducted measurements on these phones. But even then the use of different antenna connectors posed a challenge to the service centres, since they needed a cable for virtually each individual phone. The industry recognised the antenna connector as a component contributing to the manufacturing cost, power level inaccuracy and warranty claims, so most phones today only have an integrated antenna, requiring radiated measurements that make proper measurements more difficult.

This is where antenna couplers provide a solution. Antenna couplers are, in principle, antennas connected to the test equipment. Through these antennas, the test equipment communicates with the mobile phone under test. Since the attenuation in the path between the antenna coupler and the mobile phone's antenna differs from phone to phone model, this attenuation must be calculated for each model to ensure proper measurements. The challenge of course is to measure this coupling loss.

Willtek's 4916 Antenna Coupler is already a second generation antenna coupler, following the 4910. The 4916 uses a spiral antenna, which is a broadband antenna covering a large frequency range with a relatively flat frequency response. The first generation antenna coupler 4910 was using two different antennas, one for the 900 MHz frequency band and one for the 1800/1900 MHz frequency band. However, this turned out to be a disadvantage since more and more frequency bands opened up, e.g. above 2.2 GHz or in the 700 MHz range, where the performance of this band solution suffered.

VSWR of the 4916

The transmission performance of an antenna (gain, efficiency) is affected by a bad match of the involved components to the system impedance, which is usually 50 Ω[1]. In the case of the 4916 the "bad" component can be considered the antenna of the mobile phone, which usually has a very different matching behaviour. This mismatch results in additional attenuation. Table 1 gives some figures for different VSWR values.

VSWR	Mismatch loss
1.5	0.2 dB
2.0	0.5 dB
3.0	1.3 dB
4.0	1.9 dB
5.0	2.5 dB
6.0	3.1 dB

Table 1: Mismatch loss depending on VSWR

The VSWR of the 4916 is better than 2, even reaching 1.5 in certain frequency ranges. This has been tested and verified with a network analyzer. The VSWR is influenced by the device under test (i.e. the mobile phone) in the near field environment and can therefore change slightly. As a result, the device under test has an influence on the coupling loss value. This change is so much smaller than the basic VSWR of the antenna coupler! Competing products usually have a VSWR in the range of 3 to 6, which means that the feedback effect from the phone may lead to an even higher VSWR and coupling loss.

[1] The impedance of the spiral antenna used in the 4916 itself has a higher impedance due to the non-conducted transmission. A transformer within the 4916 adapts the antenna's impedance to the 50 Ω used at the connector.

Coupling loss and test limits

Coupling loss

The coupling loss of the signal from a mobile phone to the antenna coupler with constant distance is smaller, the higher the gain of this antenna. The gain of an antenna can be improved by limiting its bandwidth. This is the major difference between the 4916 and its competitors. The 4916 has a single broadband antenna ranging from 700 to 2700 MHz, whereas the competing products are using two narrowband antennas only covering the frequency bands in the 900 MHz range and the 2 GHz range. In between these two frequency bands the coupling loss and performance is most questionable, e.g. when being used for GPS signals in the 1500 MHz range, whereas the 4916 antenna has a very constant performance across the whole frequency range. Testing across a wide frequency range becomes more important with the introduction of Bluetooth, WLAN, GPS and new cellular frequency bands into mobile phones.

Constant performance also relates to the VSWR of the antenna coupler. For an antenna coupler with a high gain, the VSWR is sufficiently good only in a small frequency range, whereas for a broadband antenna the matching and therefore also the VSWR remains good over a large frequency band.

From this relationship it can be concluded that a slightly higher coupling loss of a broadband antenna coupler with a better VSWR will show a smaller variation of the coupling loss, which provides repair centres with higher measurement repeatability. Repeatability in this context means that if you use e.g. 10 test setups consisting of high-accuracy mobile phone testers (such as the 4405) and the 4916 Antenna Coupler to test one phone, the differences between these measurements will be smaller than when tested with any different antenna coupler.

The smaller coupling loss values of other antenna coupler models do not offer any advantage besides providing a higher RF power level at the test instrument. This is not necessarily an advantage since the coupling loss is compensated in the test instrument. The actual RF power level seen by the instrument for a given phone is not the important piece for accurate, repeatable measurements. It is more important that the loss due to coupling of this RF power level has been properly compensated for. This will give service centres and manufacturers an accurate measurement with the repeatability and cross-system accuracy they need to have confidence in the system.

Is a higher coupling loss an issue?

Some people perceive a higher coupling loss as an issue. However, it is not, as long as the test equipment is capable of compensating the coupling loss values. Coupling loss values are simply additive values which need to be compensated by simple math inside the test equipment. E.g. if a mobile phone transmits at 21 dBm and the antenna coupler has a high coupling loss of 20 dB, this means that 1 dBm only arrives at the test equipment's input. As long as the test equipment can reliably perform all measurements at this power level there is no disadvantage.

Figure 1 shows the dynamic range of the 4400 Mobile Phone Tester Series with the CDMA2000 System Option. In addition it shows the dynamic range of an open loop power measurement of a CDMA2000 phone. The middle bar shows how the range matches with the 4400 when using a cable connection. The right hand bar shows how the dynamic range matches when using an antenna coupler with 20 dB of coupling loss. Clearly, the 4400 has the dynamic range to perform reliable measurements even with a 20 dB coupling loss.

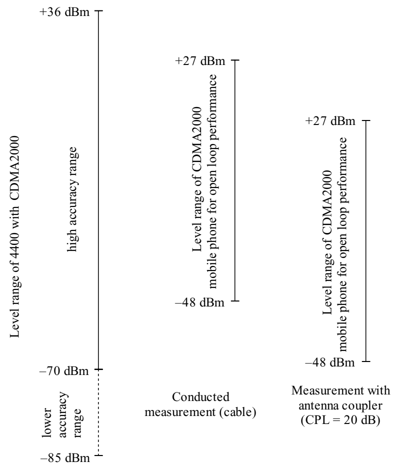
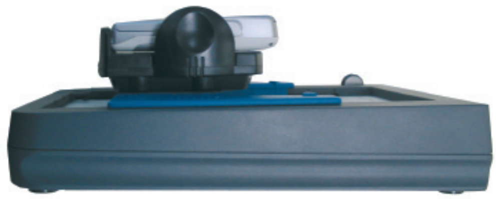


Figure 1: Matching of different level ranges to the level range of a mobile phone tester

If the coupling loss exceeds 22 dB then the level received by the 4400 is below –70 dBm. The 4400 is still able to measure the signal, although not with the specified high accuracy. The accuracy is slightly lower, but should still be acceptable and the repeatability will be the same, as each 4400 shows the same deviation.

Limits and coupling factors

Special care must be taken when calculating coupling losses and limit values which are distributed to multiple test stations. Test engineers must factor in the test equipment measurement accuracy and coupler-coupler accuracies. Currently the 4403 measurement accuracy typically is ±0.7 dB and the coupler-to-coupler accuracy is 1.4 dB or better, which is a total of 2.8 dB (2 * 0.7 dB + 1.4 dB). The upper and lower measurement limit should reflect the allowable range, the measurement accuracy and the coupling accuracy.



Marginal phones

One significant difference between direct connect and radiated testing is the uncertainty in the actual measurements. Manufacturers of wireless devices recognise this simply because there is more inherent error (or uncertainty) in a radiated test than the direct connect – this comes from the fact that the antenna coupler adds uncertainty. This difference is about 1.4 dB in the 4916 case.

The effect is not seen on most phones because they either pass or fail without being close to the test limits. If you have a phone that is performing at the edge it may sometimes pass a radiated test or fail a radiated test. It will do this on the same system or across systems. The more you tighten the limits the more this will occur. The answer lies not in the test equipment but in the process for handling marginal phones. This is why some vendors specify different limits, depending on the type of connection (cable or coupler).

A service centre needs a process for handling the marginal phone when discovered. From a customer satisfaction perspective, it is probably a good idea to calibrate (or tune) the phone to bring it up (or down) to the proper power levels at each frequency. If this cannot be done, then it should be checked for further damage. The trade-off is a financial one. A repair centre can increase the amount of tuning and decrease the number of returns. Or it can simply retune the returned phones that were sent out as good. Marginal phones are a reality and different companies treat them differently.

Conclusion

In most cases, the magnitude of the coupling loss values is not an issue; instead, the principle of the coupler determines how constant over a frequency range the coupling loss is. A high coupling loss value is not an issue as such, but a low VSWR can reduce measurement uncertainty and increase repeatability. The Willtek 4916 Antenna Coupler has been designed to be a practical tool for most wireless applications, while also contributing to the best possible measurement accuracy.

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