10/25/2011

Federal Communications Commission
Office of Engineering and Technology
Laboratory Division

MIMO with Cross-Polarized Antenna

Introduction (as a question):

For antenna-port conducted measurements on equipment with multiple outputs (e.g., MIMO), Attachment 662911 D01 of this publication specifies that the power levels from the outputs should be added. The same is also true of power spectral densities (PSDs). However, in the special case of a MIMO system with two outputs driving a cross-polarized pair of linearly polarized antennas, radiated measurements will yield a result that differs from that of conducted measurements because a linearly polarized measurement antenna aligned with one of the transmit antenna polarizations will see only the emissions from that antenna. Given that a radiated emission measurement might respond to only one output at a time in that case, the following guidance is provided to clarify the following questions.

- Is it really necessary to sum the power levels from the two outputs when performing conducted measurements?
- If summing of power or PSDs is required for conducted measurements, is such summing also required for radiated measurements?

Response:

Interpretation of requirements on output power, EIRP, ERP, or their spectral densities for equipment with two outputs driving linearly polarized antennas that are cross-polarized with respect to each other depends on the rule part and the correlation of the transmitted signals.

Unless otherwise specified in the applicable rule part, we will apply the following interpretations to cases involving transmission from linear cross-polarized antennas:

(1) Where an FCC rule specifies limits on antenna-port conducted power or *conducted* power spectral density (PSD), the rule applies to the total power or PSD delivered to the two antennas (i.e., the sum of the two powers or PSDs).

(2) Where an FCC rule specifies limits in *radiated* terms such as EIRP or ERP, the limits apply to the maximum emission that would be observed by a linearly polarized measurement antenna. For radiated measurements, the maximum need be performed only over two polarizations for the receive antenna—horizontal and vertical.

The implementation of these interpretations is described below.

Rules That Specify Conducted Limits

Where an FCC rule specifies limits on antenna-port conducted power or conducted power spectral density (PSD) (e.g., Sections 15.247, 15.407, 90Y), the rule applies to the total power or PSD delivered to the two antennas. Compliance will usually be demonstrated by conducted measurements, but radiated measurements are permitted under certain circumstances, such as for devices with integral antennas and with no provision for antenna-port conducted measurements. Power and PSD measurements must be summed across the two outputs (for conducted measurements) or across the two measurement polarizations (for radiated measurements), as described below. This interpretation applies even when power limits must be reduced based on directional gain of the transmit antenna, resulting in a limit that is similar to an EIRP limit when antenna gain is above a threshold value.

Where *conducted measurements* are used for compliance with *conducted limits*, the measured conducted output power or PSD must be summed across the outputs, as described in Attachment 662911 D01 of this publication.

Where *radiated measurements* are used for compliance with *conducted limits*, the following steps are required to ensure that the total emission power or PSD is determined for equipment driving cross-polarized antennas:
(1) Measure radiated emissions with vertical and horizontal polarizations of the measurement antenna;
(2) Convert each radiated measurement to transmit power or PSD based on the antenna gain;
(3) Sum the powers or PSDs across the two polarizations.

Rules That Specify Radiated Limits

Where an FCC rule specifies limits in radiated terms such as EIRP or ERP (e.g., Parts 27C and 90Z), compliance may be demonstrated by radiated measurements. In many cases, it is also permissible to demonstrate compliance by combining conducted power measurements with antenna gain (including array gain, if any). If the rules or applicable measurement procedures specify how to handle circular, elliptical, cross-polarization, or horizontal and vertical polarizations, follow the rule. If not, we will interpret EIRP or ERP limits as applying to the maximum emission that would be observed by a linearly polarized measurement antenna, as follows.

Where *radiated measurements* are used for compliance with *radiated* limits, measurements are performed in the usual manner, and no extra steps are required.

Where *conducted measurements* are used for compliance with *radiated* limits, the EIRP or ERP (total or spectral density) of each of the two transmit chains is computed separately based on measured output power or PSD and antenna gain. The decision of whether or how to combine the results is then made as follows.

(1) If the transmitter output signals are completely *uncorrelated* as defined in Attachment 662911 D01, of this publication, then each of the two EIRPs or ERPs (total or spectral density) must individually be below the limit.

(2) If one of the transmitter outputs is a *90-degree phase-shifted* replica of the other and the phase centers of the two antennas are co-located (as would be the case when creating a circularly polarized transmission using linearly polarized antennas), then the each of the two EIRPs or ERPs (total or spectral density) must individually be below the limit [as in (1)].

(3) If the transmitter output signals are *correlated* as defined in attachment 662911 D01 of this publication and the conditions of (2) do not apply, then the sum of the two EIRPs or ERPs (total or spectral density) must be below the limit. (See Attachment 662911 D01 of this publication regarding summing spectral densities.)

The explanation for case (3), above, is as follows. Suppose two transmit chains individually produce field strengths Ea and Eb at a point in space on the main response axis of the antennas and that the two signals are perfectly correlated at that point. If the antennas had the same polarizations, the field strengths would directly add. However, with cross-polarization the two field strengths must be combined as vectors with one oriented at a 90 degree angle with respect to the other. The combined field strength has a magnitude equal to the square root of the sum of the squares of the two field strengths, or, equivalently, the square of the combined field strength is equal to the sum of the squares of the two individual field strengths. Since EIRP and ERP are proportional to the square of the field strength, the combined EIRP or ERP is equal to the sum of the individual EIRPs or ERPs.