RF Power versus System Gain

From the very beginnings of radio, engineers have been heavily focused on RF power output. While RF power level is certainly important in any transmission system, it is one of many factors that enter into the success formula. In long, medium and shortwave communications, propagation is not line of sight and is influenced by factors that can be difficult to predict, and more difficult to overcome, regardless of power levels. In microwave, most propagation effects are well understood and system performance can be accurately predicted under all but the most unusual conditions.

Factors that effect microwave performance

When the variable effects of propagation and antennas are set aside, it is relatively easy to characterize and compare the performance of microwave systems. The key factors that should be reviewed with regard to link performance include RF power, and how it is measured; receiver threshold, and what it's based on; and modulation type. Factors like RF and IF bandwidth, are also important, and should be analyzed to be certain they are similar between different manufacturers for a given set of operating conditions. The difficulty arises in trying to read and interpret the various data sheets, which are not often comparable. Let's review some of the basics:

RF power output

Generally expressed in Watts, but much more useful when converted to dBm. For example, 12W = + 40.8 dBm. It is important to realize that the power output will change with modulation type. A transmitter capable of 12 Watts in FM mode will typically be operated at 5-6 Watts in QPSK mode to maintain sufficient linearity. As the modulation type becomes more complex, the power "back-off" factor will become more pronounced. To be useful, power output must be specified at ***ALL*** applicable modulation types, i.e. – FM, QPSK, 16QAM, and 64 QAM. A specification that reads: Power output = 10 Watts digital, is meaningless without a reference as to how this measurement was taken, and it may be misleading to a user.

Receiver Threshold

In video systems, the receiver threshold is defined as the minimum RF input level required to provide an acceptable picture on a video monitor. In accordance with EIA/TIA standards, analog FM systems use the 37 dB S/N point as the acceptable minimum, and have done so for decades.

In a digital ENG system, the threshold references are based on the minimum C/N ratio required to achieve a BER of 10^{-6}, or an average of one bit error per megabit of data. While there will be some variations due to IF bandwidth, error correction, and guard interval, the average performance of the MRC CodeRunner 4 and STRATA receivers may be characterized as follows:

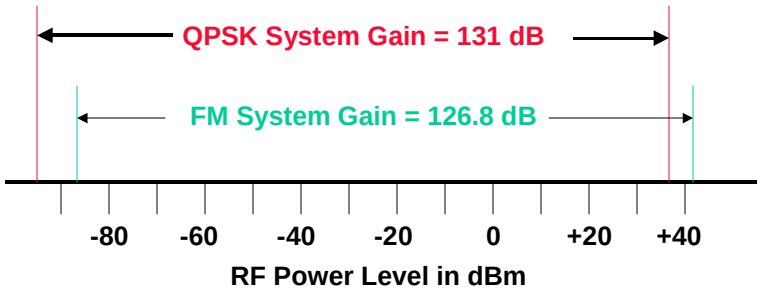
Mode	FM	QPSK	16QAM	64QAM
Rx Threshold	-86	-94	-89	-84

System Gain

One of the quickest and most useful ways to compare microwave system performance is to study system gain values. System gain is the difference in dB between the transmitter RF output power and the practical threshold of the receiver. In the chart below, the system gain of an MRC CodeRunner 2 transmitter and CodeRunner 4 receiver is compared in analog FM and QPSK modes to provide the reader with an easy way to visual reference of these parameters. It is interesting to note that the system gain in QPSK mode has more than a 4 dB advantage over the FM analog mode.

RX Threshold
FM: - 86 dBm
QPSK: – 94 dBm ½ FEC

TX Power Output
FM: 12 Watts / + 40.8 dBm
QPSK: 5 Watts / + 37 dBm



CodeRunner System Gain - 12 MHz Channel
3 MHz FM deviation
8 MHz COFDM Pedestal

Based on MRC factory measured data for transmitter power output and receiver threshold sensitivity, it is now possible to construct an accurate view of system gain under all normal analog and digital operating conditions. Table below summarizes the system gain of a CodeRunner 2 transmitter and CodeRunner 4 receiver at 2 GHz.

	FM	QPSK	16QAM	64QAM
RF Output	40	37	36	33
Rx Threshold	-86	-94	-89	-84
System Gain	126	131	125	117

CodeRunner 2 + CodeRunner 4 System Gain Values

The results illustrate how system gain varies with modulation type, and clearly reveal that some digital modes are better than, or close to analog in this regard. The only mode that underperforms legacy FM is 64QAM, which would not be deployed in the majority of ENG applications.

The Last Word….

RF output is a significant measurement with respect to a transmitter, however it is more important to study all of the RF parameters that effect microwave system performance, and how they are measured. The best way to evaluate the potential range of microwave equipment is to look at system gain, which takes both ends of the path into consideration. From the experience gained in over ten years of developing digital radios, MRC engineers know that generating one to two dB of additional transmit power in all specified digital modes typically requires the capability to generate 10 dB more in the analog mode. The additional heat, power requirements, size, weight and cost of such an amplifier is difficult to justify, and the reduced life expectancy creates a greater risk to our customer's operational reliability.

The tendency to view RF output as being the single most important parameter is understandable when looking at on-the-air broadcast transmitters, but it represents only a part of the answer in ENG and point to point microwave.